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巻　頭　言

本所は当地に開設されてから十周年に当るので，ここにそこの記念祝典を計画した。十年の歳月は此種の祝典を挙行するには短かきに過ぎるとも思われるが，ここに敢えて開講十周年を呼号する所以は，本所が終戦引揚という日本の歴史に於いて未曽有の事態に際会し，下関に再出発して，ここに10年，諸事漸くその緒につき，既設の大学と略足並を一つにするに至つたので，此の機会に更に覚悟を新たにして，精深な理想に向つて邁進することを誓うためである。

戦後の物資不足の最中に，実験設備或は練習船等理科系応用方向の各般に亘る施設を要する教育機関の新設は一層困難を極めたが，幸に農林当局の理解ある態度と地元水産関係業界，県，市等の温い援助により建設は着々と進捗し，10年を経た今日に於いては，これらの施設も概ね備い大学教育機関として一応の形態を整えるに至つたことは慶賀すべきことと思う。

この間設備の充実と相俟つて教職員の研究成果も着々と挙り，これら業績の中水産講習所研究報告として学界に発表したもの既に7巻に垂んとしている。　此度はこの7巻1号をもつて10周年記念号として上梓することとした。ここに掲載する論文は漁業，資源，生物，化学，加工等の各部門に亘り，24を選んだ。これにより本所の研究活動の一端を窺い知ることが出来るであろう。

斯くして我々は発足以来の過去を省みて，その足らざる点は更に研究を重ね新しい分野の開拓に資したいと思う。

昭和32年11月

所長　田中耕之助

Preface

It is ten years since our college was established at Shimonoseki, and we have decided to celebrate the 10th anniversary of the founding of our college. Some people may think that it is a little too premature to do so, when only a decade has elapsed since the opening of the college. But we dare celebrate this auspicious occasion. The reason is this. Our college has not always been here at Shimonoseki; it was formerly established at Pusan, South Korea, but Japan's defeat in the late war, which is unprecedented in the history of our country, compelled us to evacuate Pusan to take a fresh start here, and ten years have passed since then. At present everything is so fairly under way in our college that it can presumably stand comparison with any senior college in our country. At this juncture we are prepared to make a new determination to realize our lofty ideal for the improvement of our college.

In those hard times immediately after Japan's defeat in the late war, when the supply of goods was very difficult, it was much more difficult for us to have various educational facilities, such as a laboratory where chemical and physical experiments are made and a training ship for students. Fortunately, thanks to the sympathetic authorities of the Department of Agriculture and Forestry, under whose jurisdiction our college is placed, to those concerned with marine product industry in Shimonoseki and to Yamaguchi prefectural and the city authorities, who have all rendered help to our college, we have made good progress these ten years in improvements and intensification of equipments necessary to us. It is a matter for congratulation that the college leaves nothing to be desired for educating the students, so far as educational facilities are concerned.

Going hand in hand with those good facilities of the college, the teaching faculty are playing an active part in it, making a lot of successful researches in fisheries, which have been already made public to the academic world as the college memoirs in six volumes. Having selected from among many of our recent memoirs 24 pieces of them which treat of fisheries, marine products, specification, biophysics and biochemistry, we have just had them compiled in the the first number of 7th volume in commemoration of the 10th anniversary of the founding of our college.

This memorial volume of ours will, it is hoped, give a general idea of what we are doing in our college.

Reflecting upon our past extending over ten years after the founding of our college, we are determined to make more fruitful researches with a view to finding fresh field for further activity.

November 1957.

Kōnosuke Tanaka,
Dean of the College.

水産講習所十年誌

本所はここに開設十周年を迎えることになつたが，その開校の緒は終戦という未曽有の事態により，釜山水産専門学校の引揚げ学生を下関に収容して再出発をしたものであるから，本所の歴史を語るには必然的に朝鮮に於けるその発祥に溯らざるを得ない。

昭和16年４月元朝鮮総督府は釜山郊外大溝里に釜山水産高等学校を創設し，校長に水産講習所教授田中耕之助氏（現本所所長）教頭に水産講習所教授松生義勝氏（現東京水産大学学長）が迎えられた。後，戦時中釜山水産専門学校と改称。昭和20年終戦により韓国に接収された。同年12月，農林省はこの元釜山水産専門学校の内地引揚学生を全面的に水産講習所へ転入学を許可し，その教育のため下関市吉見在旧海軍防備隊の施設の一部の転用を受けて，水産講習所下関分所を開設したが，戦後の日本再建の上に水産教育の拡充強化の心要を認め，且地元の要望に応え，昭和22年４月，水産講習所官制の一部を改正して従来の講習所を第一水産講習所とし，水産講習所下関分所を廃止してここに第二水産講習所を設置し，所長には釜山以来の田中耕之助氏の就任をみた。第一水産講習所は昭和25年度から東京水産大学と共に文部省の所管になつたが，第二水産講習所は依然農林省の所管として存置し，昭和24年度から入学資格を新制高等学校卒業程度とし又文部省の新学制に準拠して学則を改正し，大学程度の水産教育を施す様になつた。

建物施設としては現在本館，図書館，講義室，各学科実験室，実習工場，体育館等 3,076.5坪，寄宿舎並に厚生会館等 799.5坪の他更に今般十周年記念を祝して大洋漁業株式会社社長中部謙吉氏の寄附になる記念講堂186.2坪が新営増加された。練習船俊鶻丸はもともと農林省の漁業取締船であつたものを東京水産大学の練習船として貸与していたが，昭和26年度予算で之を改装し（588屯），本所の練習船に供することになつた。爾来再度のビキニ海域の原爆被害調査並に学生の実習練習船として内航外航に従事しているが，之も昭和32，33両年度の予算で代船建造が認められ，目下 1,200屯，1,800馬力の新鋭船の竣工を急いでいる。所外実験実習場も着々と整備され，昭和29年４月，水産講習所臨海実験実習場（山口県熊毛郡平生町田名所在）同小野臨湖実験実習場（宇部市小野区小野）と改称されるようになつた。

卒業生数は昭和26年３月第１回生を送り出して以来本科643名，専攻科，144名，に達し，進出する方面は学科によつて違うが，官庁方面では国並びに地方の行政及研究試験機関，実業方

面では水産関係の各会社工場，団体等である。尚本所の卒業生は昭和24年４月，人事院規則細則により，公務員の級別資格基準に於いて，又同年10月，漁業，機関科学科の卒業生は運輸省令第91号による海事従事者国家試験の受験資格について新制大学と同じに取扱われることになつた。又昭和29年１月，学則の一部を改正して講座制を実施した。本所の教職員による研究業績は第二水産講習所研究報告として昭和24年１巻１号を刊行し，爾来号を重ねて，本年11月，ここに十周年記念号として７巻１号を発刊するに至つた。此の間，昭和27年３月，松井魁，高井徹雨氏の「東海黄海に於ける重要魚類の生態学的研究」は日本水産学会賞を，昭和29年４月，松井魁氏の「日本産鰻の形態，生態並に養成に関する研究」は日本農学賞を授与された。本所教官で学位を取得した者に，松井魁（京大，理），吉田裕（九大，農），千葉卓夫（北大，農）片田実（九大，農）等がある。

尚本所の後援会は下関の水産関係業者，市及県を主体とするものであるが，設備の整備，教職員の研究補助及教職員の宿舎の取得等本所の各種事業の助成に努め，[illegible]昭和27年度迄に25,063,646円を寄附した。

以上が本所の発足以来，過去10年に亘り辿つて来た足跡の概要であるが，ここに我々は自らの過去をふり返つて反省し，更に新しい前進を誓うものである。

（書[illegible]記）

Ten years' history of Shimonoseki College of Fisheries

It is ten years since our college was established here at Shimonoseki. But the college has not always been here ; its old home is Pusan, South Korea. In referring to the history of our college, we cannot but touch on its cradle.

In April 1941 the former Government General of Chosen established Pusan Fishery High School at Daienri, a suburb of Pusan, South Korea, and Konosuke Tanaka, the then-professor of the Fisheries Institute (the present dean of Shimonoseki College of Fisheries) and Yoshikatsu Matsuike the then-professor of the Fisheries Institute (the present president of the Tokyo Fishery University) were appointed director and senior professor, respectively. During the late war the school was renamed Pusan School of Fisheries. In 1945, when the late war came to an end, the school was turned over to the Republic of Korea, and in December of the same year the Department of Agriculture and Forestry, under whose jurisdiction the school was placed, allowed all the repatriated students of the school to be admitted into the Fisheries Institute which had been established at Yoshimi, Shimonoseki by the name of Shimonoseki Branch of the Fisheries Institute, having part of the barracks there for the use of the former Naval Defence Corps appropriated for educating those students from Pusan. In order to expand and intensify fishery education for the rehabilitation of the post-bellum Japan and comply with the wishes of Shimonoseki City people, the government revised part of its organization pertaining to the Fisheries Institute in April 1947, and the Tokyo Fisheries Institute was rechristened the First Fisheries Institute and the Shimonoseki Branch of Fisheries Institute, the Second Fisheries Institute, the name of Shimonoseki Branch being cancelled. The Second Fisheries Institute was headed by Konosuke Tanaka, who had been director of the School since its establishment at Pusan.

The First Fisheries Institute has fallen under the jurisdiction of the Department of Education since 1950, but the Second Fisheries Institute, the predecessor of the present Shimonoseki College of Fisheries, has remained under the jurisdiction of the Department of Agriculture and Forestry as ever. In April 1949 the qualifications for admission to our institute were established, by which those boys who have completed the senior high school course are admitted to our institute, and at the same time our institute regulations were reformed in accordance with the new educational system of the Department of Education, by which fishery education of a college standard is conducted in the institute. Such being the case, our institute had better be called Shimonoseki College of Fisheries hereafter.

Our college has the following buildings in its precinct : the main building ; the library; class-rooms; laboratories for students of different departments; the gymnasium;

(All these cover an area of 3,076.5 tsubo.) a dormitory and the "Koseikaikan" (a house for the promotion of the students' welfare). The last two buildings cover an area of 799.5 tsubo. Besides, a memorial hall covering an area of 176 tsubo has been newly built through the good offices of Kenkichi Nakabe, President of the "Taiyo Gyogyo Kabushiki Kaisha" (the Oceanic Fishery Co. Ltd.), who made a generous donation to the college in commemoration of the 10th anniversary of its founding. The "Shunkotsu-maru," our training ship, used to be one for the exclusive use of the Department of Agriculture and Forestry to keep watch on fishing boats, but the Tokyo Fisheries University had the loan of the ship as its training one for some time. In 1951 the ship was converted into a training ship with a tonnage of 588 for the exclusive use of our college. Since then the ship has been used for the students' practical training, and twice dispatched to the sea around Bikini Island in the South Pacific Ocean in order to investigate the extent of damage done by the nuclear energy experiments made there. But this ship will be replaced before long by a new one now under construction with a tonnage of 1,200, developing 1,800 horse power, the building of which has been included in the budget for 1956 and 1957.

As for marine laboratories for multiplication, we have two, which are kept in thorough order. In April 1954 one located at Tana, Hirao, Kumage-gun, Yamaguchi Prefecture and the other located at Ono, Ube City, Yamaguchi Prefecture have been renamed "Marine Laboratory" and "Lake Laboratory," respectively.

Our college has turned out 849 boys ; some are in the employ of the government research institutes, and others are working in private corporations and factories connected with fisheries. In accordance with the Ordinance No. 91 of the Transportation Department issued in October 1949, those who have completed either fishery or engineering course of our college are entitled to be treated on an equal footing with college graduates, when they undergo state examinations for seamen. Since January, 1954 the "chair system" on the part of the professors of our college has been adopted.

In March 1952 Prof. Isao Matsui and Assist. Prof. Tohoru Takai made public under joint authorship their "Ecological researches concerning certain important fish found in the East China Sea and the Yellow Sea," and won a prize from the "Japanese Society of Scientific Fisheries" (Nihon Suisan Gakkai). In April, 1954 Prof. Isao Matsui made public his "Morphological, ecological and reproduction researches in Japanese eels," and was awarded a prize by the "Japanese Association of Agricultural Science Societies" (Nihon Nōgaku-kai).

In 1949 the teaching faculty of the Second Fisheries Institute had the 1st number of the 1st volume of their memoirs published, and, going through several publications of their memoirs, they have had their recent memoirs, compiled in the first number of the 7th volume this year as the memorial number in commemoration of the 10th anniversary of the founding of our college.

The following professors of our college have had doctorates conferred on them; Isao Matsui has secured the degree of Doctor of Science from Kyoto University; Hiroshi Yoshida, the degree of Doctor of Agriculture from Kyushu University; Takuo Chiba, the degree of Doctor of Agriculture from Hokkaido University; Minoru Katada, the degree of Doctor of Agriculture from Kyushu University.

The "Supporters' Association" of our college is mainly composed of those who are concerned with fisheries in the City of Shimonoseki and the well-wishers in the city and Yamaguchi Prefecture. They give unsparingly of their money and effort to the college for improving its facilities and subsidizing its teaching faculty to let them have houses to live in. The money donated to the college by the association amounted to 25,063,646 yen as of 1952.

We have thus traced the outlines of ten years' history of our college. Reflecting on what we have done for the last ten years since the establishment of the college, we are prepared at this juncture to make a fresh start forward for carrying the college to the pink of perfection.

Hiroshi Yoshida
Chairman of the Editorial Committee.

印度洋東部鮪漁場の海況並びにプランクトンの分布について※

鶴田新生・佐藤猛郎・早山万彦・千葉卓夫

Oceanographical and Planktological Studies of Tuna-fishing Ground in the Eastern Part of the Indian Ocean

By

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The observed area corresponds to the waters of divergence in which part of the west wind drift in the South Indian Ocean turns to the north coming in contact with the water of the coastal origin, and then these two flow northwestward and northeastward, respectively. The result is that the line of demarcation between those waters represents an extreme meandering caused by the relative force between the waters and those off the southern coast of the Sunda Islands and the water in the middle layer is presumably as deep as the central water of the Indian Ocean (400m).

As to the occurrence and the distribution of plankton there is some difference between the northern and the southern area with lat. 15°S.～18°S. (st. 26—25—7) as a line of demarcation, where the surface temperature and the salinity are very different.

In the northern area are found *Amphisolenia bidentata, Amph. thrinax, Chaetoceros coarctatus, Rhizosolenia alata, Calanus darwinii, Euchaeta marina, Scolecithrix danae, Corycaeus gibbulus* while in the southern area a species of Foraminifera, *Lucifera raynaudii, Calanus robustior, Lucicutia flavicornis, Haloptilus longicornis, Pleuromamma xiphias.*

緒　　言

1956年11月より'57年2月に至る期間，本所の練習船俊鶻丸は第四次の印度洋鮪漁場調査をジャバ南方海域に於いて行つたが，著者の一人鶴田は乗船し該海域の海洋調査を実施して，0～500mの各層の水温・塩分その他を観測し，又プランクトンを採集した（第1図，第1表）。プランクトンの採集には口径60cm，長さ160cm，網地日本製篩絹GG54の中井式㊥ネットを使用し，水深100mより表面まで毎秒50～100cmの速さになるようにして垂直的に曳網した。本報文の作成に当つては主として海況解析を佐藤・鶴田，プランクトンを千葉・鶴田，塩分の分

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析を早山が担当した。本文の取纏めに協力を得た学生平山豪・宇津井早苗の両君に対し深く感謝の意を表する。亦，海洋調査に便宜と協力を与えられた俊鶻丸船長南四郎氏初め乗組員各位に厚く御礼を申し上げる。

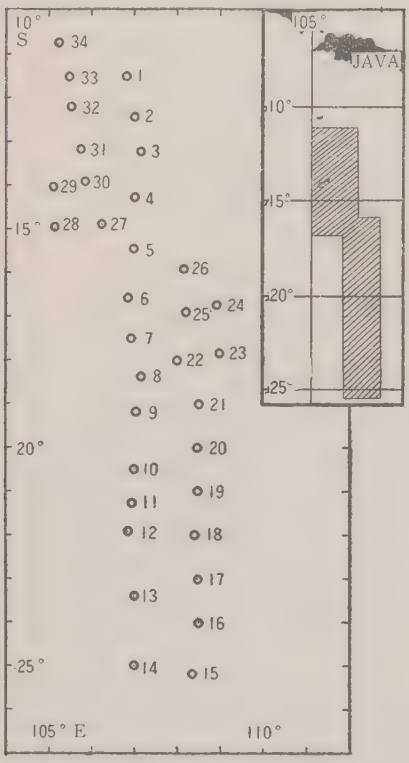


Fig. 1. Chart showing position of hydrographic stations.

海　　況

本海域は印度洋南部の西風漂流がオーストラリア西南岸に達して北西に方向を転ずる場所であり，従つて東南側には沿岸系と思われる水塊の一部が存する。北部はこの西風漂流系の水塊と沿岸系の水塊とが相接する部分で，両者の流界線がほぼ南北に走り，しかも観測線が南北の方向の二線に限られていることは海況解析を困難にした。

1. 水温及び塩分の水平分布（第2図）。

この海域での水平面に於ける等温線の分布配置状況は0～400mの各層において，程度の差こそあれ，いずれも著しい蛇行性を示している。この特徴は等塩分線でも認められ，多分，この水域が東西両水塊の相接する場所に当ることを示すものであろう。

全般的に，水温は南するにつれて低くなるが，特にこの水域の中部すなわち15°～18°Sで勾配はもつとも大きい。深くなるにつれて蛇行している等温線は漸次その走向が南北方向に移り，深さ400mの層では大体南北に走つている。

塩分では200m以深で早くも等塩分線が水域の中部以南でほぼ南北に走るようになり，概して北の方ほど塩分が低くて，100m以浅では水温の場合と同じく15°～18°S付近で最も変化が大きい。

2. 水温及び塩分の垂直分布

A. 水温（第3図）。北部のst. 1～4及び30では0～25mは殆んど変化せず，st. 1，2，3，5，6，30及び31では50m以深がほとんど同じ変化型に属し，50～300mではほぼ一様に低下し，300m以深がやはり一様な低下を示している。それ故50～300m層が，かすかではあるが変水層に当る。st. 4は他の何れとも異なる水温変化の型を示し，50～150m及び150m以深でそれぞれ異なる水温の低下率を示し，前者が変水層をなすものと思われる。st. 32～34ではほぼ25mから150mまでst. 4に似た水温低下の傾向を示すが，それ以深，150～300m及び300m以深がst. 4のそれに対応しないそれぞれ別々の変化型を示している。そしてこれらの諸測点（st. 1～4及びst. 29～34）では深さ450m附近で同じ水温の値をもつ。

中部ではst. 21，23～25がほとんど同じ水温の変化型を示し，25m以深で一様に低下している以外に，これ等と他のst. 7，8，22及び26～28の間及び各点相互間に類似の変化型は認められない。唯，st. 27が150m以浅でst. 29～31に近い変化を示すにすぎない。しかも400～450mでは各点の温度はかなり違つている。

Table 1. Investigation period and hydrographic conditions

Station			Date	Weather	Water colour	Transparency (m)	Deposition of plankton (cc)	Water temperature (°C)										Salinity (‰)										Remark	
No	Lat. (S)	Long. (E)						0m	25m	50m	75m	100m	150m	200m	300m	400m	500m	0m	25m	50m	75m	100m	150m	200m	250m	300m	400m	500m	(m)	(m)
1	11—29.5	106—50.5	Dec. 27	b c	—	15.5	6.5	28.60	28.53	28.51	26.80	24.10	21.31	17.22	11.59	9.62	* 9.06	33.93	34.03	34.10	34.13	34.16	34.31	34.40	34.41	34.42	34.48	—	*	433	
2	12—24	107—05	27	b c	—	26.5	9.2	28.30	27.81	27.10	25.35	23.32	19.52	16.27	11.74	9.68	* 8.38	33.80	33.90	34.02	34.14	34.26	34.65	34.78	34.80	34.82	34.74	—	*	476	
3	13—15	107—10	27	b c	—	—	7.2	26.70	26.26	26.20	24.88	23.70	20.48	16.33	—	—	—	34.11	34.13	34.15	34.16	34.16	34.46	34.49	-	-	—	-			
4	14—17.7	107—05	28	b	—	35.7	6.7	27.80	27.42	26.67	23.43	22.46	17.67	15.57	13.10	9.98	* 8.46	—	34.13	34.17	34.24	34.45	34.67	34.74	34.74	34.76	-	—	*	489	* 350
5	15 -28	107—01	28	b c	—	—	9.8	26.90	26.65	25.43	23.58	21.65	20.15	17.21	13.28	10.38	8.47	—	34.27	34.25	34.34	34.61	34.69	34.79	34.81	34.83	34.72	—			
6	16—36	106—53	29	b c	—	38.0	10.0	26.70	26.82	25.36	23.58	22.40	20.08	17.10	12.50	10.09	* 9.06	34.04	34.13	34.22	34.42	34.61	34.69	34.69	34.76	34.74	34.55	—	*	485	
7	17—30	106—59	29	b c	1	34.0	9.8	28.10	26.29	25.74	25.02	22.51	20.52	18.74	13.72	10.70	* 9.15	34.13	34.16	34.18	34.18	34.25	34.76	34.80	—	34.81	34.76	—	*	476	
8	18—22.5	107—11.5	29	b c	—	—	13.1	24.90	24.20	24.20	22.36	22.00	21.28	19.42	15.57	11.11	*10.04	34.60	34.61	34.63	34.65	34.70	34.80	34.86	34.91	34.95	—	—	*	457	
9	19—12	107—35	30	b c	—	—	—	24.40	24.07	24.01	22.84	22.28	21.31	19.46	17.22	*11.29	—	—	—	-	—	34.76	34.88	34.94	34.94	34.93	—	—	*	375	
10	20—28	107—0.15	30	b	2	40.0	5.6	24.30	23.76	22.78	21.88	21.08	19.93	19.00	16.53	*12.54	—	34.58	34.82	34.83	34.83	34.83	34.87	34.90	34.90	34.89	34.86	-	*	386	
11	21—17.5	106—59	30	b	—	—	9.1	23.75	23.51	22.50	21.51	20.58	19.32	18.24	13.65	—	—	—	34.58	34.76	34.81	34.81	34.81	34.82	34.83	34.77	—	—			
12	21—54	106—54	31	b	2	32.0	6.5	23.40	23.11	21.52	20.78	20.28	19.43	17.79	13.27	*11.31	—	34.67	34.67	34.71	34.75	34.83	34.86	34.86	34.85	34.82	—	—	*	360	
13	23—26	107—00	Jan. 1	c	1	28.0	8.2	23.00	22.93	21.50	20.13	19.39	18.00	16.32	12.73	10.08	* 9.44	34.65	34.67	34.70	34.73	34.76	34.83	34.83	34.83	34.81	34.72	*34.69	*	433	* 450
14	25—00	107—00	1	b c	2	29.0	10.6	23.14	23.00	22.31	20.50	19.42	17.63	16.41	12.46	*11.83	—	34.69	34.69	34.70	34.77	34.79	34.86	-	-	—	—	-	*	321	
15	25—12.5	108—21	2	0	—	—	7.2	22.50	22.49	21.80	21.00	20.11	18.02	16.49	14.98	12.00	*10.13	—	-	34.60	34.60	34.60	34.63	34.69	34.70	34.71	34.72	—	*	470	
16	24—00	108—36	2	b c	1	24.0	23.6	23.40	22.12	21.41	19.81	19.00	17.60	15.58	*12.93	—	—	34.76	34.79	34.85	34.87	34.88	34.94	34.98	34.97	34.95	—	—	*	265	
17	23—00	108—29	2	b	—	—	—	23.60	23.50	22.73	21.27	20.09	18.72	17.33	14.28	*11.97	—	34.78	34.79	34.81	34.83	34.86	34.89	34.90	34.93	35.04	—	—	*	360	
18	22—00	108—25.5	3	b c	1	22.0	9.4	23.60	23.00	22.50	21.26	20.24	18.09	17.68	13.50	—	-	34.74	34.77	34.84	34.90	34.90	34.92	34.90	34.84	-	-	—			
19	21—00	108—30	3	b c	1	33.0	12.3	24.30	24.00	22.87	21.41	20.20	19.10	17.70	13.98	*10.67	—	34.63	34.65	34.68	34.75	34.80	-	-	—	—	—	—	*	383	
20	20—00	108—30	3	b c	—	—	15.9	23.40	23.30	22.86	21.44	20.25	18.30	16.12	11.61	* 9.32	-	34.67	34.67	34.67	34.70	34.75	34.84	34.90	-	-	-	—	*	372	
21	19—07	108—33	4	b c	2	26.0	7.3	24.50	24.30	23.61	22.50	21.40	19.78	18.00	14.00	*10.04	—	34.65	34.66	34.68	34.70	34.72	34.77	34.82	—	—			*	372	
22	18—00	108—02	4	b	2	35.0	6.2	24.80	24.50	24.00	23.00	21.73	20.29	19.08	16.27	12.00	*10.42	34.56	34.62	34.69	34.74	34.78	34.85	34.91	—	—	—	—	*	441	
23	17—50	109—00	4	b c	—	—	11.3	24.90	24.77	23.31	22.00	21.10	19.85	18.41	14.50	10.70	* 9.85	34.49	34.51	34.57	34.66	34.73	34.85	34.89	34.94	—	—	-	*	424	
24	16—46	108—57	5	b	2	31.0	7.2	25.40	25.00	24.48	23.20	22.43	20.50	18.61	14.23	9.82	* 9.38	34.42	34.43	34.45	34.47	34.50	—	—	—	—	—	—	*	415	
25	16—57.5	108—16	5	b c	—	—	9.0	25.90	25.48	24.00	22.81	22.20	20.23	18.63	14.71	10.45	* 9.39	34.33	34.37	34.42	-	—	—	—	—	—	—	—	*	424	
26	15—57	108—10	6	0	2	39.0	12.0	27.00	26.74	26.31	24.30	23.00	20.00	15.73	11.42	* 9.77	-	34.67	34.45	34.15	34.21	34.35	34.70	34.87			—	—	*	383	* 175
27	14—54	106—18	7	0	1	26.0	9.4	27.10	26.75	26.50	24.30	22.85	20.59	18.40	13.60	9.60	* 8.32	34.24	34.24	34.24	34.24	34.42	34.70	34.82	34.83	34.83	34.84	*34.91	*	457	* 450
28	14—57.5	105—09	7	0	—	—	11.1	27.00	27.06	26.36	23.88	22.00	18.00	16.00	13.30	9.60	* 8.94	34.15	34.11	34.15	34.16	34.28	34.68	34.64	34.29	34.50	34.75	*34.66	*	433	* 450
29	14—04	105 - 08	8	0	1	26.0	7.0	27.60	27.31	26.53	24.73	23.00	20.40	16.73	13.21	10.45	* 8.56	34.07	34.07	34.20	34.20	34.32	34.84	34.96	—	34.88	34.70	*34.55	*	470	* 450
30	13— 55	105—52	9	b	2	34.0	5.2	27.50	27.31	27.26	24.92	23.50	19.73	17.34	12.15	9.77	* 8.52	34.07	34.07	34.07	34.07	34.21	34.60	34.78	—	34.67	34.54	*34.47	*	464	* 450
31	13—13.5	105—46	9	b c	—	—	6.8	27.80	27.52	26.94	25.97	23.99	20.51	17.00	11.65	9.92	8.53	34.11	34.09	34.05	34.07	34.20	34.38	34.65	34.63	34.60	34.74	34.81			
32	12—15	105—36	10	b	1	34.0	5.5	28.65	28.36	27.13	25.97	24.31	18.86	15.65	10.78	9.65	8.17	34.22	34.25	34.13	34.13	34.20	34.61	34.81	34.82	34.83	34.70	34.63			
33	11—37	105—28	10	b c	—	—	12.6	28.50	28.21	27.20	25.37	23.75	18.39	15.32	11.00	9.50	* 8.45	34.15	34.16	34.13	34.11	34.32	34.42	34.94	34.60	34.48	34.45	34.47	*	485	
34	10—46	105—15	11	b	2	34.0	7.7	28.90	28.93	27.60	24.48	22.23	18.24	14.73	10.61	9.80	* 8.17	34.24	34.30	34.42	34.38	34.36	34.38	34.38	34.39	34.40	34.61	—	*	481	

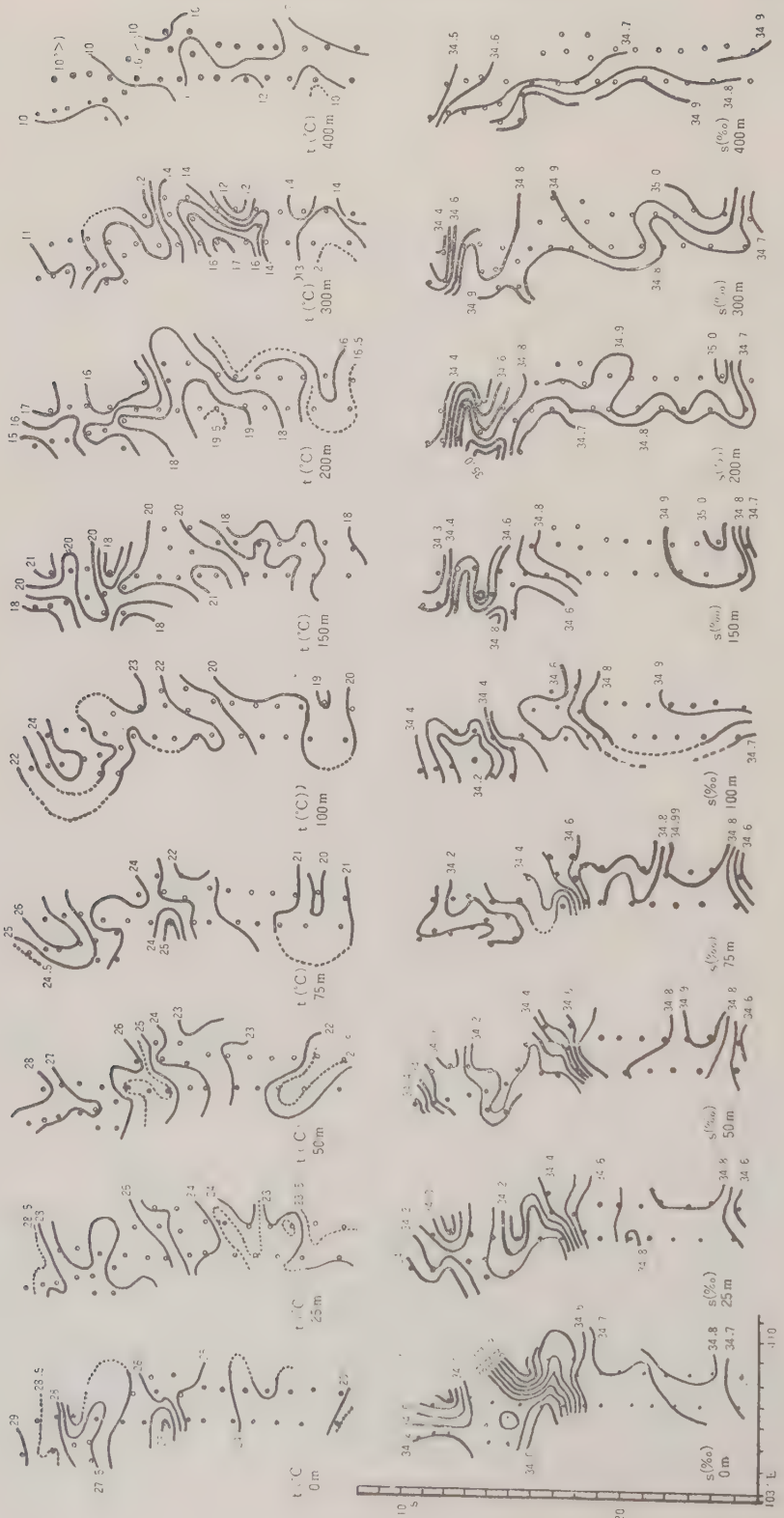


Fig. 2. Horizontal distribution of water temperature and salinity.

南部では st. 12及び17～19が類似した変化型を示し，st. 13, 14及び16が 150m 以浅でほぼ同じ低下を示す他は，中部に於けるように各点の垂直変化は大幅に違つている。

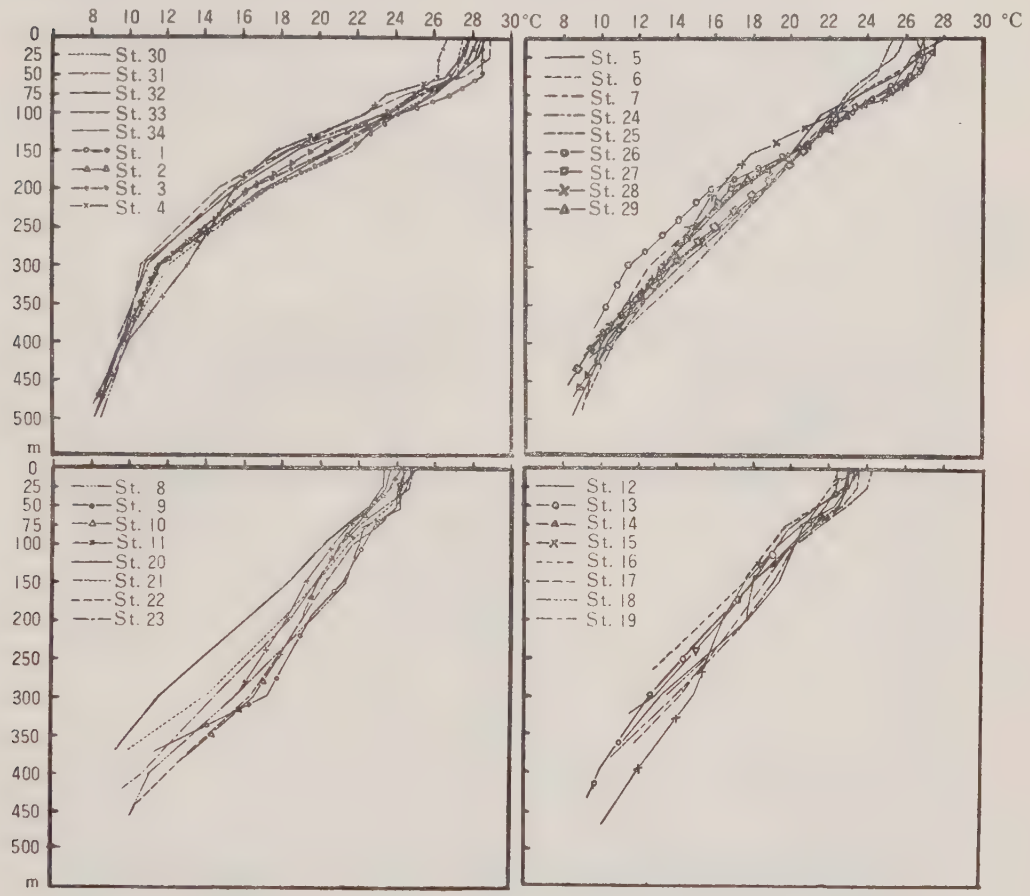


Fig. 3. Vertical distribution of water temperature.

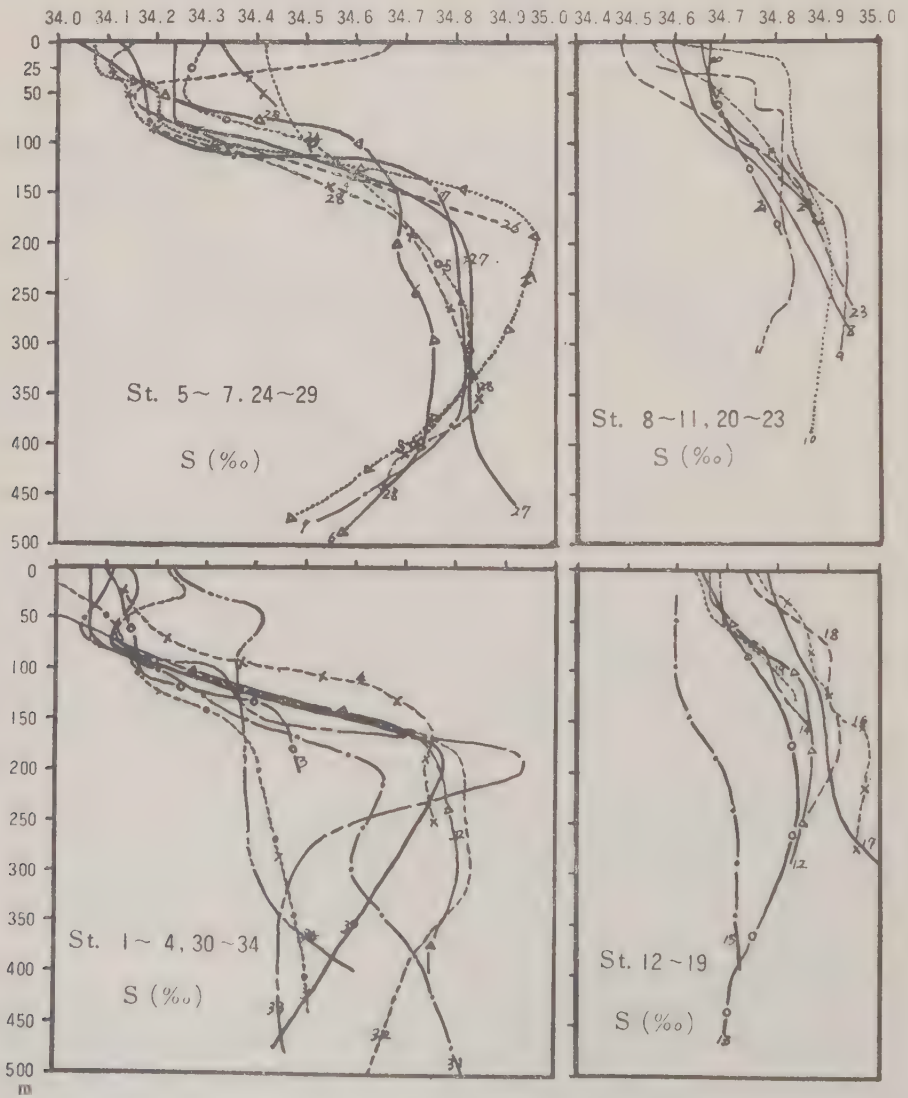
B. 塩分（第4図）。st. 2 と St. 4 (50～150m)，st. 2 と st. 4 (50～150m)，st. 2 とst.27, 28（いずれも50～350m）及び st. 2 と st.29, 30 (50～200m) 及び st. 2 と st.32 (50～400m) はそれぞれよく似た塩分の変化型を示し，st. 2 についてみれば 0～150m の間で増加の割合が最も大きく，200～400m では大体同じで，極大値が200m 又は300m にみられる。その他の各点はそれぞれ独自の変化型を示しているが，特に st.34 では 0～50m で著しく増加して50m に極大値を示した後，100～300m ではほぼ同じ値を示し，その後再び増加する。又 st.33 では著しく不規則で，75m に極小値を示した後 75～100m 及び 150～200m で著しく増大して 200m に極大値を現わした後著しく減少して，300m 以深ではほぼ同じ値をもつ。st.27, 30では 0～75m がそれぞれ同じ値をもつている。

中部の st. 5～17及び st.27, 28 はかなりよく似た垂直変化を示しているが，st. 6 では 50～100m，st. 7 で 100～150m（著しい），st.27 及び 28 で 100～200m にそれぞれ塩分の変化の著しい層が認められ，st. 5 と 6 では 300m 前後，st. 7 では 200～400m に極大値があり，かつ st. 7 では他の各点と異なつて 200～400m でほとんど変化を示さずその後再び増加している点

が異なつている。

st. 8, st.19～23 の各点は 0～200m 又は 250m まで漸増しており相似の変化型を示すものと思われるが，それ以深での観測値が欠けているのでよくは解らない。これ等諸点に較べて，st.26 は著しく異なつており 50m の極小値の上下での変化率は極めて大きく，又 st.25 は 0～50m の塩分値しか得られていないけれども st. 6 と共に表層の値が著しく低い。

南部の各点に共通な特徴は，北部及び中部でみられたような深度に伴う大きな塩分変化がなく，表面及び 400m 位の深度の間の変動の大きさは精々 0.2‰ 程度にすぎず，st.17 を除けば 150m 前後又は 200～250m 前後に極大値を示した後と減少している。そして東側の各点は西側に較べて稍々高鹹であり，又，st.15 は 0～100m 及び 200m 以深の各層内がそれぞれほとんど同じ値をもち，他の何れの点よりも低鹹である。



Figi. 4. Vertical distribution of water salinity.

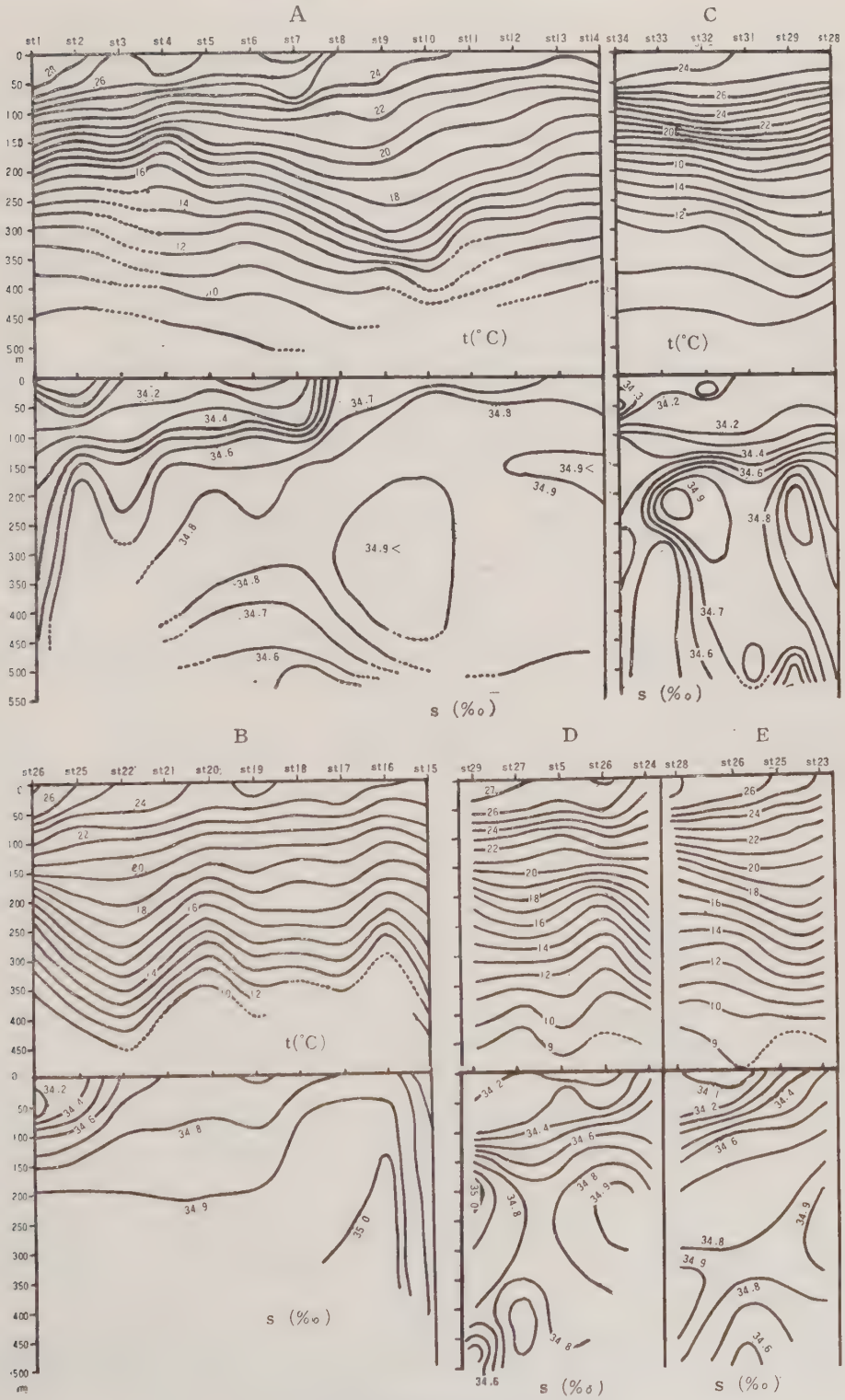


Fig. 5. Vertical sections A, B, C, D and E.

3. 垂直断面

この海域では，水温の著しい不連続層が認められないこと及び等塩分線と等温線の激しい対応が認められない。また，著者の一人佐藤が1953～54年冬に大スンダ列島南方で海洋観測を行つた際に 400m以深に認められた様な温度変化の小さい層が，この海域には見当らない。

A．断面A（st. 1～14）（第5図）。ほぼ南北方向のこの断面では高温低鹹な北方系の水がst. 1～7の表層を占め，一方南からの低温高鹹水がかなりの厚さをもつて伸びていて，前記北方系水の下に潜入し，水温躍層はかすかではあるが st. 1～4での 100～150m附近から南するにつれて深くなり，st. 9で 300～350mに達し，その後浮上してそれと同時に一層漠然としたものになつていて，中層水と表層水との境界を示し，一方，st. 4～7での75m前後から st. 7と8の中間で表面に終る南北両水塊を境する躍層が認められる。

B．断面B (st.26～15)（第5図)。断面Aにほぼ平行なこの断面では，やはり激しい水温躍層は認め難いが，st.26の75m附近からst.25の少し南で表面に浮上するもの(断面AでのSt. 7と8の間の躍層に対応する）及び断面全範囲に亘つて250～300m付近を波状に上下する弱い躍層が感じられる。この断面で特に注目すべきはst.16と15の間での等塩分線がほとんど垂直であることであり，これは st.15が st.16及びそれより北の水と全く異なる系統のものであることを示す。

C．断面C（st.34—28）（第5図)。断面Aの北部に対応してその西側に位置し，この断面では100～150m附近にかなり著しい水温躍層が認められ，塩分の躍層もこれにほぼ対応している。唯，断面Aの北部と異なる点は st.34 の 50m 附近に著しい高鹹部があり，これに伴つて st.34 の 75m 附近より漸次浮上して st.32 と 31 の中間の表面に終る等塩分線（34.2‰）以浅の高鹹高温 28°C 以上の水が存在することである。つまり，この点に，北西及至西方から高温高鹹水が圧していることを示すものと思われる。

D．断面D（st.29—27—5—26—24）及び断面E (st.28—6—25—23)（第5図)。いずれもほぼ NW—SE の方向に走る互いに平行な断面で，水温の著しい躍層は明らかではないが，塩分では st.29～26 での 100～150m 附近から st.24 附近で表面に浮上する躍層と，st.28の100m前後から st.25 の少し北西方で表面に浮上する躍層（いずれも34.4‰前後）とが認められ，従つて断面Aでの st. 7～8，Bでの st.25 附近及びDでの st.26～24 の間を通る 100m 以浅の水界線があるものと考えられる。

4. 水　　塊

T-S-ダイアグラム（第6図）より解るように，この水域では，表層（0～100m）に6，亜表層（150～200m）に4，中層（300m以深）に2の水塊が認められる。

i. 表　　層

水塊A．st.34の50m前後に中心をもつ（実際にはもつと北西又は西方に中心があろう）もので，t＝27～28°C，s＝34.40～34.45‰の，大スンダ列島南西岸或いはその沖合に起源を有するもの。

水塊B．st. 1～7，26～33の各点の75～100m 以浅にみられる t＝23～29°C，s＝34.0～34.3‰のAよりも低鹹な水塊で，これはジャバ南東岸沖合で相当深い所まで存する水塊から南に伸びた舌状部の先端であろう。

水塊C．st. 8，9，11，19～25各点の75～100m以浅に存する t＝21.0～25.0°C，s＝34.4～34.7‰の水塊で，いわば水域全体の亜表層に蟠居する水塊の頂層であり，st.18では僅かに表面に名残をとどめている。次の水塊Dと同じ系統で，塩分だけがDよりも低い。

水塊D．st.16～18のごく表層に存する，Cよりも高鹹な水塊で，本海域中部以南の亜表層以深を占める，多分インド洋東部の外洋系水の頂層。

水塊E．st.12～14の50～75m以深にあつて，t＝20～23°C，s＝34.70～34.75‰で，st.10～11の表層を介して前記のCに連なり水塊Dをおおつている。西方系のものであろう。

水塊F．st.15にあつて，この点より北～北西側のどの水塊とも性質を異にする水塊でt＝20～22°C，s＝34.6～34.7‰の高温低鹹水。おそらく，オーストラリア南西～西岸の沿岸水であろう。

ii. 亜 表 層

水塊G．st.1，3，31，33及び34の150～200mに存するt＝16～21°C，s＝34.35～34.50‰の，多分ジャバ南岸沿いに東方に張り出した水塊。

水塊H．st.2，4～6，27～30及び32の150～200mを占め，t＝15～20°C，s＝34.6～34.8‰で，前記のGの下層を占めているが南するにつれて漸次浮上し次の水塊Iをおおう。

水塊I．st.8～14，16～18，20及び22～26の150～250m層に存し，t＝17～20°C，s＝34.80～34.95‰で，st.15のすぐ北に南限をもつて北上する水塊で，その一分枝は北東のst.24～26の方に向い，他の一分枝はst.27の200m層に貫入している。

水塊J．st.15の150m以深300m位までに認められるt＝15～18°C，s＝34.6～34.7‰の水塊で，表層での水塊Fと同じ系統のものである。

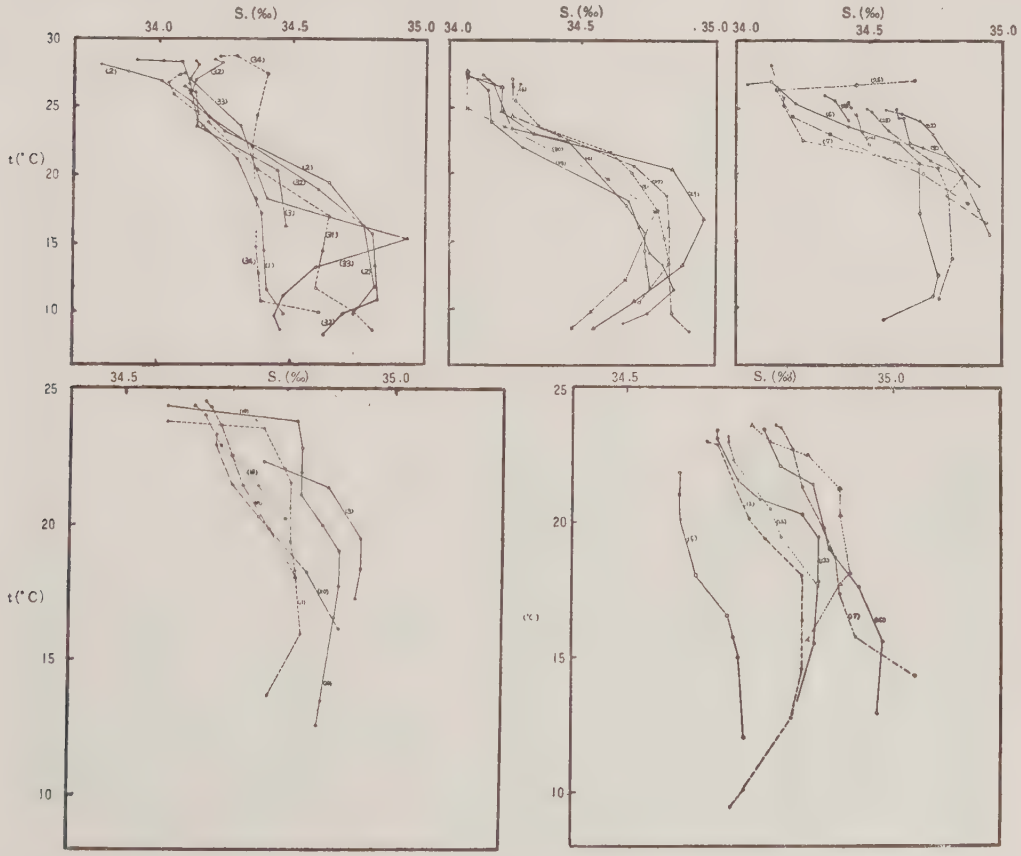


Fig. 6. T—S—Diagrams.

iii. 中　　層

水塊K．st.1，30，33及び34の300m乃至450mにわたる t = 8～12°C，s=34.35～34.50‰の水塊。

水塊L．st.2，4～7，13，27～32及び34に亘つて300～400m以深を占める t= 8～12°C，s=34.60～34.85‰のKより高鹹な水塊。

以上に属さないものは st.27の450m層（t= 8～9 °C，s=34.85～34.95‰），st.29の450m層（t= 8～9 °C，s=34.55～34.65‰），及び st.30の400m層（t= 9～10°C，s=34.50～34.55‰）であるが，st.27は水塊Lに近く，st.29及び30は K，L 両水塊の中間型である。

既に述べたように本海域はインド洋南部を東進する西風漂流の一分枝がオーストラリア南西岸に当つて北西に進路をかえた許りの部分と，オーストラリア西岸の沿岸を北東に進む沿岸流との接触・分岐する地点である。従つて流界線の形状は両者の勢力の相対的関係によつて規定されるものであり，水温及び塩分の水平分布にみられた等スカラー線の著しい蛇行性はその証拠であると考えられる（第7図）。

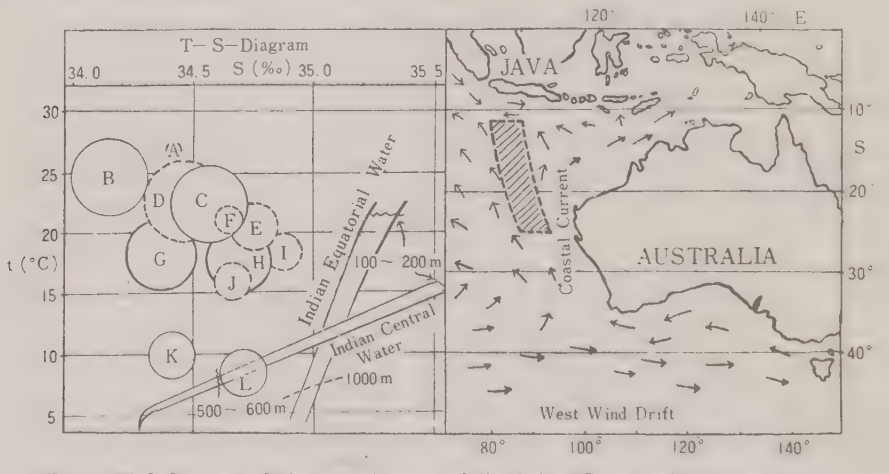


Fig. 7. T-S-Diagram of the central water of the Indian Ocean and water masses.

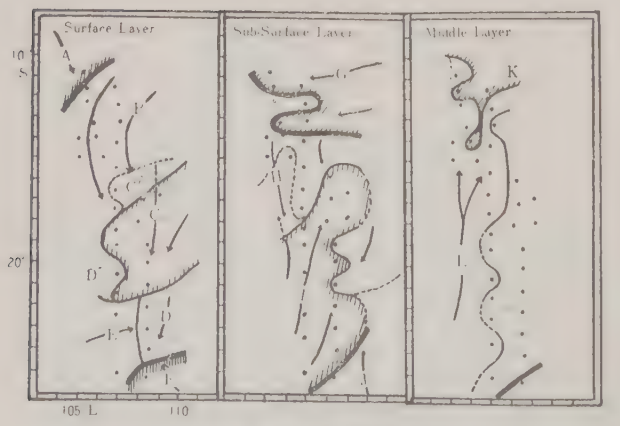


Fig. 8. Water masses.

従来知られている処ではインド洋中央水のT-S-ダイアグラムでは，100～200mで；t=14～16°C，s=35.4～35.5‰，500～600mで；t= 7～8 °C，s=34.6～34.7‰の帯状域で表されている。それに基いて判断すれば本海域で考えた各水塊の中で，中層の水塊Lだけがこの中央水に含まれる様である（第7図）。尚，第8図に各水塊及びそれ等の張出し経路を示す。

Table 2. Occurrence of the plankton

Species \ Station	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
COPEPODA																																
Calanus	*tenuicornis*		RR	RR			RR	RR	RR		RR			RR	RR	RR	RR	R	RR	RR	RR	RR	R	R		RR			RR	RR	RR
C.	*gracilis*		RR																							RR						
C.	*helgolandicus*	R	RR	RR	RR	RR		RR		RR	RR						RR		RR	RR			RR	RR	RR	RR			RR		
C.	*darwinii*	CC	C	C	C	C	+	R	R	R	R	R					R						+	+	+	+	R	+	C	C	C	C
C.	*vulgaris*		RR	RR																								RR	R	R	R	R
C.	*minor*	R	R	RR	RR	R	RR	R		RR			RR								RR		RR	RR	RR	RR	R	RR		R	RR	R
C.	*vrbustior*		R	R	RR	RR	RR	RR	R	R	R	RR	R	+	+	-		+	R	+	R	C	+	C	-	C	+	RR	R	RR	+	R
C.	*pauper*	RR	RR	R	RR	RR	RR	RR	R	R	R	RR	RR			R					RR	R	R	R	R	R			RR	RR	RR
C.	*plumchrus*												RR																			
Eucalanus	*subcrassas*		RR						RR				RR	R	R	+	+	R		R	R	RR	R	R	RR	R	R	RR	RR	RR	RR	RR
Eu.	*attenuatus*	C	+	+	+	+	R	R	R	R	-	+	R	+	RR	-	+	+	RR	+	+	+	+	+	+	+	+	+	R	+	+	+
Eu.	*elongata*		R	RR			RR						RR				R									RR	R					
Eu.	*mucronatus*	R	RR							RR	RR	RR	RR	RR		R			R		RR	RR	R	RR				RR	RR	+	R	R
Rhincalanus	*cornutus*	RR	RR																		RR	RR				RR			RR	RR		
Acrocalanus	*gracilis*	RR	RR	RR	RR	RR		RR	RR		R	RR	R	+	R	RR	RR	RR	R	RR	R	R		RR	RR	RR	R		RR	RR	R	R
Acro.	*gibber*		RR	R	RR		RR		RR	RR	RR	R	R	R	R	R	RR	R	R	R	R	R	RR	RR	-	RR	R	R	RR	R	R	R
Acro.	*monachus*		RR	RR	RR	RR		RR	RR		RR	R	R	R	RR	RR	R	R	R	R	R		RR	R	R	R	RR	R	R	R	R	+
Paracalanus	*aculeatus*	C	C	+	+	+	+	+	+	+	C	+	+	+	C	+	C	+	+	+	+	C	+	C	+	+	C	+	+	C	C
Para.	*parvus*	RR							RR		RR										RR											
Clausocalanus	*furcatus*			RR		RR		RR	R	R	R		R			R	R	R	R	RR	R	+	R	R	RR		R		R	RR	RR
Clauso.	*pergens*		R	RR	RR	R		RR	R	+	+	+	+	+	+	+	+	+	R	R	+	R	R	+	+	+	C	+	+	+	+	+
Clauso.	*arcuicornis*	+	C	+	+	+	+	+	R	+	+	C	+	+	C	+	+	+	R	+	+	C	C	+	+	C	+	C	+	C	C	C
Calocalanus	*pavo*	RR	RR	RR	RR	RR	RR	RR	+	+	+	R	R	R	R	RR	+	+	+	R	R	R	+	R	+	R			?	RR		
Calo.	*plumolosus*		RR	RR		RR																	RR						RR			
Scottocalanus	*helenae*												RR																			
Pseudocalanus	*elongatus*			RR			RR		RR	R	RR		RR	R		RR	R	R	R	R	-	+	+	+	+	R	+	+	+	+	+	+
Bradyidius	*armatus*				RR								RR			RR	RR	RR														
Euchaeta	*marina*	CC	CC	CC	CC	CC	C	C	+	+	C	+	K	+	RR		RR	R	R	+	+	+	R	C	C	CC	CC	C	+	C	C	+
Euch.	*plana*																			RR	R			R								
Euch.	*wolfendeni*																												R			
Euch.	*concinna*														RR		R												RR			
Euch.	*longicornis*											R	R			R	RR	RR	RR	RR	R		RR									
Lucicutia	*flavicornis*	RR	R	R	R	RR	R	RR	R	+	+	+	R	R	-	+	-	+	+	+	+	R	R	R	+	+	R	R	R	R	R	R
Luci.	*ovalis*									RR																		RR				
Heterorhabdus	*papilliger*				RR	R		RR		RR	RR	RR	RR	RR		RR		R		RR	RR	RR		RR	RR		RR					
Hetero.	*spinifrons*										RR	RR	RR								RR											
Haloptilus	*oxycephalus*												RR				RR															
Halo.	*actifrons*		RR	RR	RR	RR		RR				RR	RR	RR	RR		+	RR			RR	RR			RR					RR	RR	
Halo.	*ornatus*			RR	RR		RR					RR	RR	RR				RR			RR		RR									RR
Halo.	*longiconis*						RR			RR	RR	RR	R	R	+	+		+	R	R	RR	R	R	RR	RR	RR						
Halo.	*spiniceps*																R				RR	RR			RR							
Mecynocera	*clausi*							RR	R	R	R	R	R	RR				R				R	R		RR		RR	RR	RR	RR	RR	
Scolecithrix	*danae*	+	C	+	C	+	R	R	R	R	R	R	RR	RR	RR	R		+	RR	+	R	R	+	R	+	R	+	+	+	+	+	+
Euchirella	*grandicornis*						RR										RR					RR			RR							
Euchi.	*galeata*				RR	RR																				RR	RR	RR				
Euchi.	*amoena*				RR	RR	RR				RR		RR	RR								RR	RR	RR	R	R						
Temora	*discaudata*	RR	RR	RR						RR	RR		RR	RR				RR		RR	R	+	R	R	RR		RR	RR				
Temo.	*stylifera*			RR	RR	RR	R	R	+	+	R	R	RR	RR	RR			+	R	R	RR	R	+	+	R	RR						RR
Lophothrix	*latipes*																						R	RR	RR	R	R					
Lavidocera	*pavo*	RR		RR	RR																			RR	RR			RR				
Lavido.	*detruncata*														RR	RR	RR							RR	R							
Lavido.	*euchaeta*				RR	RR	RR	RR		RR	RR	KR		RR								RR	RR	RR		RR			RR	KR	RR	
Centropages	*calaninus*							RR	RR	RR	RR	RR	RR	RR	RR			RR		RR		RR				RR			RR	RR	RR	RR
Cen.	*furcatus*												RR			RR			RR				RR					RR				
Cen.	*elongatus*											RR	RR				RR															
Cen.	*vradyi*								KR	RR	RR	RR	RR		RR		RR	RR											RR	RR	RR	RR
Cen.	*gracilis*															RR																
Candacia	*aethiopica*			R			RR		RR	RR	KR	R	RR	RR	RR	RR							RR	K	+	+	R	RR	R	R	RR	RR
Can.	*vradyi*		RR																							R						
Can.	*discaudata*				RR	RR																										
Can.	*simplex*							RR	R			RR	RR																			
Can.	*catula*	RR	RR				RR		RR												RR	RR		RR	RR	RR						
Can.	*curta*		+					KR	R	RR	RR	KR				RR					RR			RR	RR	R		RR		RR		
Can.	*vispinosa*			R	R	R	KR	RR	F				RR	RR				RR	RR	RR	RR			+	+	+	R		RR	R		RR
Can.	*truncata*		R		RR	RR												RR					RR	RR								
Can.	*pectinata*				RR	RR																RR						RR				RR
Can.	*logimana*								RR										R			R				R						
Can.	*pachydactyla*			KR	R	R	KR	RR				RR											R		R		RR			RR		
Can.	*pacifica*				RR																											
Can.	*vipinnata*																		RR			RR							RR			

Species \ Station	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Clytemnestra scutellata																						R R										
Cly. rostrata						R R																										
Scolecithrithricella minor		R R	R R																													
Pontellina plumata																							R R	R R	R R				R R			
pontella indica		R R																														
Phenna spinifera											R	R												R R								
Acartia clausi	+	R	R	R R	R R	R	R	+	+	+	+	+	+	+	+	R	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Acar. hamata											R R	R R	R R	R R	R	R	R	+	+	+			R	R R					F	R	R	R
Acar. neligens	R R	R R		R R	R R		R R	+	R	+	+	+	R	R R	R R	R R	R R	R R		R R				R R								
Acar. erythrea	R	R R		R R	R	R																		R R	R R	R						R R
Acar. danae			R R	R R	R R																			R R	R R	R R	R	R R	R	+	+	+
Acar. longiremis		R R		R R	R R	R	R R	R R	R R	R R	R R	R R	R								R R		R R	R R		R	R	R R	R	R R	R R
Pleuromamma abdominalis					R R			R R							+	R R															
Ple. robusta			R R		R R																											
Ple xiphias			R R	R R	R R	R R		+		R					+	R R		C	+	C	C	+	C		R R	C		R R		R R	
Ple. gracilis																				R R	R R	R	R	R R		R R	R R	R R			R R	
Aetideus armatus	R R	R R	R R	R R	R R	R R						R R	R R	R R	R R			R R	R R	R R	R R		R R	R R	R R	R R		R R	R	R R	R
Aeti. giesbrechti	R R		R R			R R	R R	R R	R R	R	R	R	R R		R R		R R	R	R	R R	R R		R R	R R	R					R R
Lubbockia squillimana																						R R	R R				R R					
Setella gracilis																					R R		R R		R R	R R			R R		R R
Euterpe acutifrons										R R			R R																			
Miracia efferata		R R	R R	R R		R R		R R			R R										R R	R R	R R	R R	R R	R R	R R		R R	R R	R R
Copilia miravilis		+	+			R	R	R R	R R	R	+	+	R	R R	R R			R R	R R		R R	R R	R R	R R	R R		R R		R R	R R	R R
Copi. longistylis		R R	R R				R R	R R	R R	R R		R R	R R		R R		R R	R	R R		R R	R R	R R				R R	R R		R R	R R
Copi. quadrata	R R	+				R R	R	R R	R R		R R	R R	R		R R																	
Sapphirina gastrica		R R		R R	R R					R R	R R	R R	R R	R R	R R	R R	R R	R R			R R	R R				R R					
Sap gemma						R R	R R	R R	R R	R R	R R	R R			R R				R R					R R	R R							
Sap. nigromaculata	R	R R		R R	R R				R	R	R R	R R	R R	R R	R R	R R	R R	R R			R R					R R					R R
Sap. stellata			R R			R R	R R	R R		R R		R R									R R				R R						
Sap. darwinii						R R	R R	R R		R R							R R		R R				R R		R R						R R
Sap. opalina		R R										R R					R R				R R		R R	R R	R R						
Sap. angusta						R R		R R	,	R R			R R																		
Sap. metallina				R R		R R	R R				R R	R R	R R		R	R R	R R	R R		R R	R R	R R	R R	R R	R R					R R	R R
Corycaeus speciosus	R	R	R	R	R	R	R R	R	+	+	+	R	R	R R	R	+	R	+	+	R	+	R	+	R	R	R R	R R		R	R	R	
Cory. lautus	R R	R R			R R		R R	R R	R R	R R	R R		+	R	+	+	+	+	+	+	R	R	+	+	+	R	R		+			-
Cory. gibbulus	R	R	+	+	R	R	R	R	+	+	R	R R	R R	R R		R	C	+	+	+	C	C	C	C	C	C		C	C	C	C	C
Cory. concinnus	R R	R R		R R				R R	R	R			R R						R R		R R	R R	R	R R		R	R				
Cory. longistylis	R	R	R			R	R R	R		R R	R R	R R	R R	R R		R R		R R	R R	R	R R	R	R R		R R	R R	R R	R R	R R	R R	R
Cory. flaccus		R R		R R	R R	R		R R	R R		R R	R R	R		R	R R				R R	R R		R R	R	R R			R R	R R	R R	
Cory. caius				R R		R R	R R	R R		R R	R R	R	R R						R R	R R	R R		R R		R R		R R		R R	R R	
Cory. ovalis	R R	R R			R R	R R	R R	R R	R R			R R	R R				R R				R R		R R	R	R R			R R	R R	R	R
Cory. crassiusculus	R R	R R	R R		R R		R	R	R	R	R	R	R R	R R	R	R R				R	R R	R	R	+	R	R	R					
Oithona plumifera	C	·	+	C	C	C	C	C	C	C	C	C	C	+	+	+	+	+	+	+	+	C	C	+	C				R	C	C	C
Oith. decipiens	R R	R	R R	R R	R R	R	R	R	R	R	R	R	R	R	·					·	·		R		·	R	R R	R R		·	·	
Oith. rovusta				R R					R R			R R			R R		R R	R	R	R	R R	R	R	R	R	R	R R	R R	R R	R	·	
Oith. setigera		R R	R R	R R	R R	R R	R	+	+	+	R	R	+	R	+	R	+	+	R	+	R	R	R	+	+	R	+		R	·	·	
Oncaea venusta	R	R	R	+	·	·	·	C	C	C	·	C	C	·			R	R	·	·	C	C	C	C	C	C	·	·	C	C	C	C
On. conifera	R R	R R	R	R R	R						R	+	R	R	-	R R	R	R	R	R	+	+	+	+	+	R	K	R	R			R
On. mediae	R R	R	R	R R	R R	R R	R	R	+	R	R	+	R	R	+	R	R	R R	R	R	+	+	+	C	+	-	R	R	R		-	
AMPHIPODA																																
Viblia viator																		R R					R R			R R					R R	
Oxycephalus porcellus		R R				R R												R R					R R			R R						
Phronima pacifica					R R							R R			R R	R R		R R			R R			R R		R R			R R		
Phronima sp.			R R		R R	R R	R R	R R	R R	R R		R R	R R			R R	R R	R R	R R	R R	R R	R R	R R	R R	R R	R R	R R		R R			R R
Leptocotis amvobus			R R																													
Parascaelus zebu			R R	R R	R R				R R	R R	R R	R R	R R		R R		R R	R R	R R		R R	R R	R R		R R	R R	R R	R R	R R	R R	R R	
Phronimopsis spinifera	R R	R	R R	R R									R R	R R	R R			R R		R R												
Hyperia sibaginis	R R	R R	R	R R									R R	R R	R R	R R		R R														
Hype. sp				R R		R R	R R	R R	R	R R	R R	R R	R R	R R	R	R R	R	R R	R R	R R	R R	R R	R R		R R	R R	R R	R R	R R	R R	R R	R R	R R
Anchylomera blossevillii								R R										R R		R R												
Scina borealis sp.					R R			R R	R R	R R				R R	R R		R R	R R								R						
Rhabdosoma brevicaudatum																									R R							
Leptocotis ambobus									R R																							
Themisto gracilipes													R R				R R			R R												
SCHIZOPODA																																
Euphausia gracilis		R R			R R		R R	R R		R R		R R			R R	R R		R	R R	R R	R R		R R					R R		R R	R R
Eu. gibba				R R	R R			R R						R R	R R		R R	R R	R R		R R	R R	R R	R R		R R	R R		R R	R R	R R
Euphausia krohnii		R R	R	R R	R R	R R	R R	R	R R	R	R R	R R	R R		R R	R R	R R	R R		R R	R R		R R	R R	R R	R R	R R	R R		R R	R R	R R
Thysanopoda obtusifrons			R R		R R	R R										R R	R R	R	R R	R R	R R	R R	R R	R R	R R	R R			R R	R F	R R
Thy. tricuspidata			R R	R R	R R					R	R R	R R		R R	R R	R R															
Stylocheiron carinatum		R R	R R		R R	R R	R R	R R							R R						R R			R R						

specis \ station		1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Stylocheiron	*suhmii*				RR				R				RR			RR			RR			RR	RR		RR		RR			RR		
Stylo.	spp.										R												RR								RR	
Sirietta	*thompsoni*			RR	RR	RR		RR	RR			RR							RR					RR			RR					RR
Siri.	sp.			RR		RR		RR	RR					RR		RR		RR	RR								RR					
DECAPODA																																	
Lucifer	*raynaudii*		R	RR	RR	RR		RR	+	+	R	+	RR	+		+	R	RR	+	R	R	R	+	+	R	RR	RR	RR		RR		RR	
Others	Decepoda	RR		RR	RR	RR		RR	R	RR		RR	RR	RR	R	RR	RR	RR	R	RR	RR	RR	RR	RR	RR	RR	RR	RR		RR		RR	
OSTRACODA		RR	R	C	R	R	-	RR	R	RR	R	RR	R	R	C	C	R	C	R	RR	R	C	RR	C	CC	R	C	RR	R	RR	C	C	C
GUSTOROPODA		RR	C	C	RR	R	RR	RR	CC	R	R	C	RR	C	C	CC	R	CC	C	R	C	CC	C	C	C	RR	CC	R	R	RR	RR	R	RR
PLANKTON	LARVAE																																
Fish	larvae	RR	RR	R		R	RR	RR	+	RR	RR	RR	R	RR		R	RR	RR	R	RR	RR	+	RR	R		RR	R	RR		RR	RR	R	RR
Zoea							RR						RR				RR																
Furcilia	stages	R	+	C	+	C	C	C	CC	+	+	+	R	RR	R	+	R	+	C	R	+	C	R	CC	+	+	C	+	RR	+	R	+	R
Fish	eggs	RR	RR	R	R	+	R	R	+	RR	R	RR	R	RR	R	RR	RR	R	R	RR	C	R	RR	RR	R	R	R	R	RR	RR	RR		
MEDUSAE				+	R	+	R	R	+	R	R	RR	R	R	R	C	RR	RR	R	RR	R	+	RR	R	RR	R	R	RR	RR	R	R	+	
POLYCHAETA			RR	RR		R	R	RR	R	RR	R	RR	R	R	R	RR	RR	R	RR	R	RR	C	RR	+	RR	RR	R	RR	RR	RR	RR	RR	RR
CHAETOGNATHA		R	+	+	-	CC	C	CC	C	+	+	R	+	+	RR	C	R	+	+	+	+	+	+	C	CC	+	+	RR	RR	+	R	+	
Oikopleura	spp.	RR		R	C	+	+	+	+	R	RR	RR	+	RR	RR	RR		RR	R		RR	R	RR	R	RR	R	R	RR	RR	RR	RR	R	R
Doliolum	sp.		RR	RR		RR	RR	RR		RR				RR	RR	RR						RR		RR	RR	RR	RR	RR	RR			RR
PROTOZOEA																																	
Collozoum and	*Sphaerozoum*	RR	RR	RR	RR	R	RR	RR	RR	R	RR	R	RR	RR	R	RR	RR	RR	R	RR	R	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR
Aulacantha	*scolymantha*	RR	R	+	R	R	R	RR	RR		RR		RR	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR		RR	RR	RR	RR	RR				RR
Acanthometra	sp.	RR	RR	RR	RR		RR		RR				RR		RR	RR	RR	RR	RR			RR			RR			RR	RR				
Globigerina	*bulloides*	RR	RR	RR	R	R	R	RR	RR	RR	RR		RR		RR	RR	RR	RR	RR			RR	RR	RR	RR	RR	RR	RR	RR		RR	RR	
A species of Foraminifera			RR		RR			RR	+	+	C	+	C	C	+	+	R	C	C	C	-	R	+	+	RR		RR		RR			RR	
Pyrocystis	*pseudonoctiluca*	R	+	C	C	C	C	+	C	+	R	+	+	+	+	C	+	C	C	C	C	C	C	CC	C	C	+	C	R	R	R	+	+
P.	*fusiformis*							RR		RR		RR		RR	RR	RR	RR		RR	RR		RR	RR	RR									
P. hamulus cl.	var *inacquatum*						RR	RR																									
Amphisoleia	*bidentata*	RR	RR	RR	RR	RR	RR	RR	RR												RR			RR	RR	RR	RR	RR	RR	RR	RR	RR	RR
Amphi.	*thrinax*					RR	RR	RR													RR		RR			RR		RR		RR		RR	RR
Ceratium	*extensum*																RR												RR				
Cera.	*carriense*		RR	RR	R	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR	RR		RR	RR		RR	RR	RR	RR	RR	RR	RR	RR		
Cera sumatranum	f. *angulatum*		+		+	RR			RR		RR	RR			RR		RR		RR		RR	RR		RR	+	RR		RR		RR			
Ceratium	*inflexum*			RR	RR		RR								RR																		
Cera.	*tenue*				RR				RR			RR		RR			RR									RR							
Cera.	*karstenii*		RR				RR	RR										RR		RR		RR											
Cera.	*macroceros*			RR		RR							RR	RR					RR	RR	RR		RR	RR					RR				
Cera.	*massiliens*						RR			RR	RR				RR		RR	RR	RR	RR									RR	RR	RR		
Cera.	*pulchllum*			RR	RR				RR		RR		RR		RR																		
Cera.	*pennatum*															RR					RR			RR									
Cera.	*vultur*					RR		RR				RR						RR			RR			RR					RR	RR			
Cera.	*deflexum*							RR																									
Cera.	*trichoceros*																							RR									
Cera.	*lunura*		RR	RR		RR			RR				RR				RR														RR		
Cera.	*contortum*					RR		RR											RR														
Cera.	*reticulatum*						RR			RR									RR	RR								RR					
Cera.	*inflatum*															RR																	
Cera. fusus	subsp. *seta*												RR	RR	RR																		
Cera.	*belon*																				RR												
Cera.	*pentagonum*														RR																		
Phyto plankton																																	
Chaetoceros	*coarctatus*	RR	RR	R	RR	RR	RR	RR	RR										RR	RR			RR	RR		RR			RR	RR	RR	RR	RR
Chaeto.	*peruvianus*	RR	RR	RR					RR																								
Cosinodiscus	spp.		RR	RR	RR	RR	RR	RR	RR	RR	RR			RR	RR	RR	RR	RR	RR		RR	RR		RR			RR		RR	RR		RR
Rhizosolenia	*alata*	RR	RR	RR	RR	RR	RR	RR	RR	RR				RR												RR		RR	RR	RR	RR	RR	RR
Rhizo.	*imbricata*		RR	RR		RR	RR														RR			RR		RR		RR		RR	RR		RR
Rhizo.	*styliformis*	RR	RR	RR			RR	RR	RR	RR						RR										RR		RR	RR	RR	RR	RR	RR
Rhizo.	*Bergonii*			RR			RR	RR						RR	RR			RR			RR		RR	RR	RR	RR					RR	
Thalassiothrix	*longissima*		RR	RR	RR	RR	RR	RR							RR			RR			RR		RR	RR					RR			
Th.	*frauenfeldii*				RR				RR																								
Tricodesmium	spp.	RR	R	R	R	RR	RR	CC	R	RR	RR	RR	RR	RR	RR	RR	+	+	C	+	+	+	C	C	R	+	R	R	RR	RR	C	RR	R

Abbreviations : CC···Very Common, C···Common, + ···Present, R···rare, RR···Very rare

プランクトンの組成並びに分布

第2表にプランクトンの組成及び出現状況を示したが，全標品を通じて多量出現した順序にプランクトンの種属を列挙すると，橈脚類，毛顎類，翼脚類，十脚類，介形類，腹足類，浮游性被嚢類，端脚類，水母類，幼体類，有孔虫類，放散虫類，鞭藻類，甲藻類，珪藻類，多毛類の広範囲に亘り，これ等採集されたプランクトンの標品中各地点共に橈脚類が，その過半数以上を占める。

橈脚類で同定出来たものは118種に及び，これ等は地点により夫々出現の状況は異つたが，各採集点に普通に出現したものに *Calanus robustior* (特に st.14～26の南東部に多量出現)，*Eucalanus attenuatus*, *Paracalanus aculeatus*,, *Clausocalanus pergens*, *Clauso. arcuicornis*, *Scolecithrix danae* (st. 1～5, 27～34に多量出現)，*Acartia clausi*, *Corycaeus lautus*, *Corycaeus gibbulus* (特に st. 19～34 に多量出現)，*Oithona plumifera* (全地点に多量出現)，*Oncaea venusta* (全地点に多量出現) が挙げられる。

橈脚類で出現量の多い種類，若しくは特徴ある出現を示した代表的種類の分布状況を第9図A，Bに夫々示した。即ち *Calanus darwinii* (st.1～4, 31～34)，*Euchaeta marina* (st.

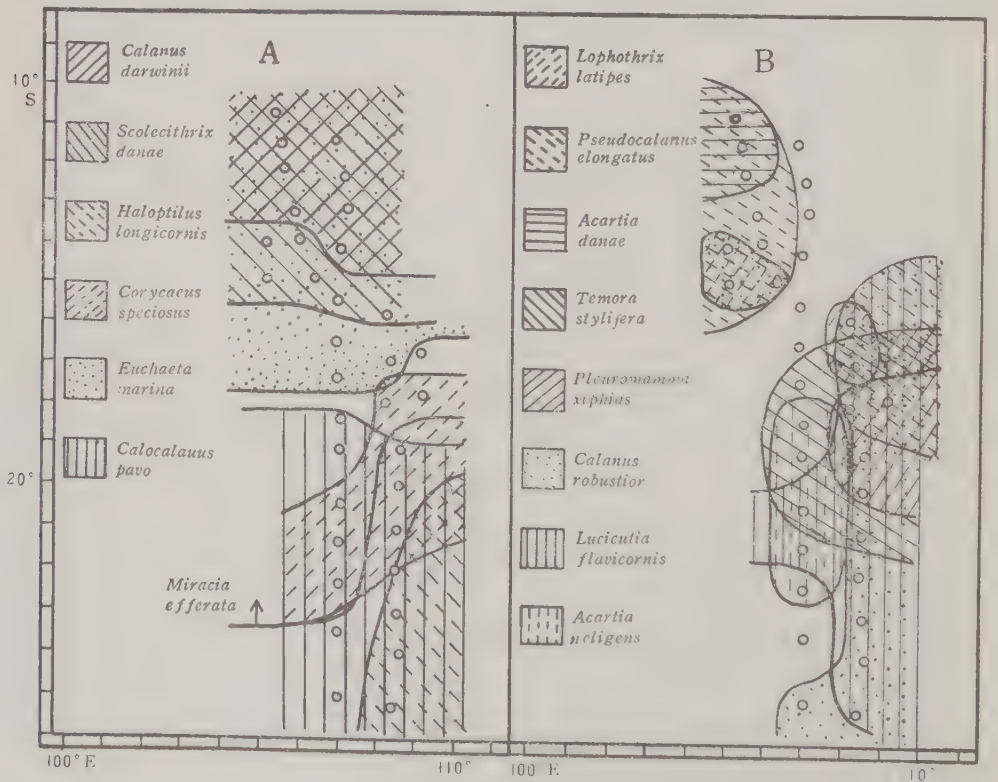


Fig. 9. Horizontal distribution of copepods.

1～7, 25～34)，及び *Scolecithrix danae* (st. 1～5, 27～34) の3種は調査海域の中央部より北部に，*Calocalanus pavo* (st. 8～21)，*Haloptilus longicornis* (st. 15～19) 及び *Corycaeus speciosus* (st.10～13, 18～23) の3種は中央部より南部海域に多量分布した。又出現率は低いが *Miracia efferata*, *Labidocera euchaeta* (第10図) 等が st.11—

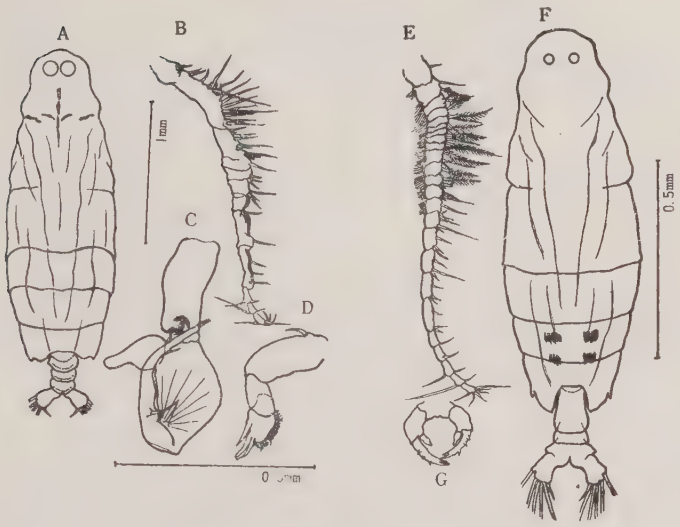


Fig. 10. *Labidocera euchaeta* Giesbrecht
A. Dorsal view (♂) B. Ist antenna (♂)
C. Right 5th foot (♂) D. Left 5th foot (♂)
E. Ist antenna (♀) F. Dorsal view (♀)
G. 5th pair of feet (♀)

23の線以北に出現した。以上の分布状況は明らかに既述の上層水の等温線並びに等塩分線の走向に従つており分布の境界は水温・塩分変化の急な 15°S～18°S の間にある。又南部に於ける境界線の走向は等温線等の様に南北に変化している。B図の様に *Calanus robustior* (st. 14～26, 27～29), *Pseudocalanus elongatus* (st. 22～34), *Lucicutia flavicornis* (st.10～11, 15～26), *Temora stylifera* (st. 7～10, 19, 24～25), *Lophothrix latipes* (第11図)(出現量は少ないが st.25～29), *Acartia neligens* (st. 8～12), *Acar. danae* (st.32～34), *Pleuromamma xiphias* (st.20～25) は経線的又は局部的に多量出現した。これらの分布状況は第3表に示す様に主として既述の表層水塊による影響を多分に受けた結果と思考される。

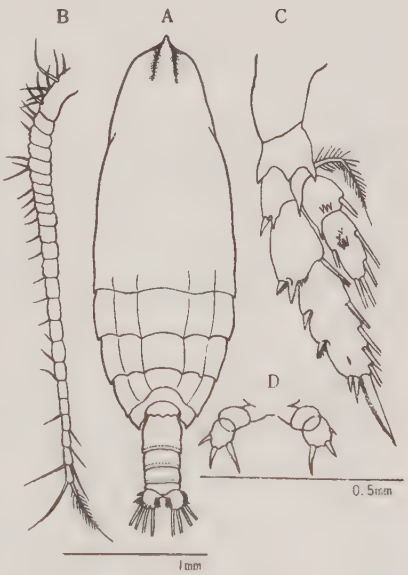


Fig. 11 *Lophothrix latipes* (T. Scott)
A. Female, dorsal view.
B. 〃 , 1st antenna.
C. 〃 , 4th foot.
D. 〃 , 5th pair of feet.

端脚類では *Phronima*, *Parascalus* 及び *Hyperia* 等の諸属の種が検出されたが, その出現度は低く僅にst.3,16,19,20,28の点に15個体以上の出現をみた。

裂脚類では *Euphausia krohnii*, *Euph. gracilis*, *Euph. gibba*, *Stylocheron* 属の2～3種のオキアミ類及びアミ類の *Siriella thompsonii* 等の種属がその代表的なものであつたが, これ等は st. 3, 5, 8, 11, 20, 28等の中央から北部海域に亘つて多く分布した。又特に幼体 Furcilian stage の出現量が極めて多かつた。

Lucifer raynaudii は温熱帯海域に広く分布し大西洋で研究された処では北緯40度以南に多く就中南北緯10度の間即ち赤道区域に最も多く分布するとされている。又本種は元来群集して出現することは寧ろ稀で他の浮游性甲殻類等に混じて僅かに採集されるのが普通とされているが，本海域では全般に亘つて分布し，st. 8, 10, 16, 20, 24, 25の点では一回の採集に30個体以上検出された。

介形類の出現度も一般に高く *Cypridina* 等の属が主なものであるが詳細は後報に譲る。

毛顎類は橈脚類に次いで量的に甚だ多く，これ等は *Sagitta serratodentata pacifica*, *Sag. enflata*, *Sag. regularis*, *Sag. minima*, *Sag. hexaptera* 及び *Pterosagitta draco* 等がその主な組成をなし，st. 5～7，26～27の中央海域に多量（各点200個体以上）出現した。

腹足類では *Atlanta*, *Cavolinia*, *Diacria*, *Clio*, *Styliola*, *Creseis* 等の種属が出現したが，特に *Atlanta*, *Creseis* 両属の出現頻度は著しく st. 8，16，19，28に多量検出された。

幼体類は低調ではあるが，殆んど総ての地点で魚類の稚仔及び卵が検出された。一回の曳網で10尾以上の稚仔を得たのは st. 5，8，16，20，23，25，28の各点であつた。

原生動物では有孔虫，放散虫類，鞭藻類等で，これ等の内特徴ある分布状況を示したものは有孔虫類の一種及び鞭藻類の *Amphisolenia bidentata*, *Amphi. thrinax* で，前者は st.10～24の東南海域に偏して多量分布し，後者は st. 1～8，24～34の北部海域にのみ少量ではあるが出現した。

珪藻類の出現状況は極めて低調で，出現種数10余種に過ぎず *Chaetoceros coarctatus*, *Rhizosolenia alata*, *Rhizo. styliformis* 等少量が st. 8—20の線以北の点に出現した。

藍藻類の *Tricodesmium* は各地点に検出されたが，st. 7，20，24，25の中央部海域に多量出現した。

海況の項に既述した表層の各水塊と主要プランクトンの分布状況を比較すると第3表の様になり，A水塊に *Calanus darwinii*，B水塊に *Euchaeta marina*，C水塊に *Tricodesmium* sp., *Lucifer raynaudii*, *Pleuromamma xiphias*，D水塊に *Haloptilus longicornis*, *Calanus robustior*，E水塊に有孔虫類の一種，F水塊に *Haloptilus longicornis*, *Calanus robustior* 等の種類が夫々優占的又は特異な出現として各水塊を指標し得る。しかし地点によつては隣水塊の潜入等あり，隣水塊と酷似したプランクトンの出現があつた。例えば水塊Cに於いては隣接水塊B，D及びEのプランクトンの組成に共通した点が認められ，水塊DとEにてはプランクトンの様相は良く類似して相違は殆んど認められない。

概略的にプランクトンの分布は水塊Cを境界として南北に大きな相違が認

Table 3. Differences of the distribution of various species according to different surface water masses.

Species \ Water mass	A	B	C	D	E	F
A species of Foraminifera	RR	RR	+	+	C	+
Amphisolenia bidentata		RR	RR			
Amphi. thrinax		RR	RR			
Chaetoceros coarctatus	RR	RR	RR			
Chaeto. peruvianus		RR	RR			
Rhizosolenia alata	RR	RR				
Rhizo. Bergonii		RR	RR		RR	RR
Tricodesmium sp.	R	R	C	R	RR	RR
Lucifer raynaudii	RR			RR	RR	RR
	RR	R	C			R
Acartia danae		RR				
Acar. negligens			R	+		
Calanus darwinii	C	C	R			
Cal. robustior	RR	R	+	+	R	+
Rhincalanus cornutus		RR	RR			
Pseudocalanus elongatus	RR		+			
Lophothrix latipes		RR				
Euchaeta marina	+	CC	+	RR	+	RR
Lucicutia flavicornis		R	+			
Haloptilus longicornis		RR	R		R	
Scolecithrix danae			R	R	RR	RR
Temora stylifera	RR	RR	R		RR	RR
Pleuromamma xiphias		RR	C	R		
Miracia efferata	RR	RR	RR			
Corycaeus speciosus	RR	R		R	R	RR
Cory. gibbulus	C	C	C		RR	RR

められるが，水塊Cの北縁に当る南緯15～18度は水温及び塩分の変化の著しい所で，これがプランクトン分布の境界線となつているものと思考する。

尙本邦近海で，未報告の *Lophothrix latipes* WILSON の雌について記せば，頭部は第一節と癒合し，頭端は尖り，背面隆起を有する。前体部は五節よりなり最後胸節は稍々尖る。後体部も五節からなる。前体部と後体部の比は4：1である。

$$\text{前体部諸節}\ \frac{1\quad 2\quad 3\quad 4\quad 5}{68\quad 14\quad 10\quad 5\quad 3}=100$$

$$\text{後体部諸節}\ \frac{1\quad 2\quad 3\quad 4\quad 5}{42\quad 17\quad 17\quad 10\quad 14}=100$$

又肢は短かく，幅より稍々長い。第一触角は24節からなり，生殖節の後端を越す。第四脚は内外葉共三節からなり，内葉第2，3節には数個の小棘を有する。第五脚は3節からなり左右相称で，末端節は三小棘を有し，内方の一棘は他の二棘より稍々長く，前縁に細羽毛を有する。雌の体長は2.4～2.9cmである。本種は T. SCOTT は *Scolecithrix* 属に入れたが SARS は之を *Lophothrix* 属とした（第11図）。亦 WOLFENDEN は雌を記載し，*Scolecithrix acutus* なる新種としたが C. B. WILSONは雄も記載し *Lophothrix latipes* としたものである。*Labidocera euchaeta* の雌雄は第10図に示した。

摘　　要

本海域は南インド洋の西風漂流の一部がオーストラリア南西側に当つてそこの沿岸水と相接しつつ北上し，それぞれ北西及び北東に流向を転ずる分流地点に相当し，これらの水塊及び大スンダ列島南岸沖合の水塊との間の勢力の相対的関係に基く著しい蛇行した流界線を示す。尙，中層（400m以深）の水はインド洋中央水の東端に相当するようである。

プランクトンの出現状況並びに分布は南緯15～18度（st. 26—25—7）の線で南北両海域に多少の相違が認められる。即ち北部海域には *Amphisolenia bidentata*, *Amph. thrinax*, *Chaetoceros coarctatus*, *Rhizosolenia alata*, *Calanus darwinii*, *Euchaeta marina*, *Scolecithrix danae*, *Corycaeus gibbulus* 等，南部海域では有孔虫類の一種，*Lucifer raynaudii*, *Calanus robustior*, *Lucicutia flavicornis*, *Haloptilus longicornis*, *Pleuromamma xiphias* 等が検出された。

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0 °Cの条件下に於けるビンナガ鮪幽門垂プロテアーゼと基質（カゼイン）との複合体に就いて※

藤井　実・西野　イチ

On the So-called Enzyme-substrate-compound Formed from Protease Extracted from Powder of Long Fin Tuna *Thunnus alalunga* and Casein under the Condition of 0°C

By

Minoru Fujii and Ichi Nishino

We studied on the formation of Protease-casein-compound (-Symplex-) at 0°C. The results obtained are as follows : the formation of the so-called symplex began as soon as protease and casein were mixed, and its maximum quantity was obtained in about eight minutes.

酵素作用の機構に関しては未だ決定的な説はないが，基質が酵素表面に結合することが酵素作用の第1階梯であるといわれる。[1] 即ち酵素が基質を分解する場合，先ず酵素と基質の複合体を生じ，次に酵素分子が基質を分離するとき基質を分解するといわれている。

B. Chance[2] はペルオキシダーゼの研究に於いて酵素－基質－複合体の存在を吸収スペクトルの変色の観察に依り証明した。著者等は魚類幽門垂プロテアーゼの研究に於て其の基質として主にカゼインを使用しているが，該酵素も其の至適条件に於いて瞬間的にカゼインと複合体を作り次の瞬間には基質を分離すると共に基質分子の分解を行うものと当然推定出来る。それならば酵素－基質－複合体の分離速度をおそくすることによつて所謂酵素－基質－複合体を捕捉することが出来るなら酵素の精製及び単離を行う上にも好都合であると考えた。そこで酵素の分解力を抑える手段として使用する試薬及び反応液の温度をすべて 0 °C に保つたが，之に依り酵素の基質分解速度を抑制すると共に基質に対する親和力を尚温存せしめ所謂複合体の生成を時間的に捕捉することが出来た。

実　験　の　部

酵素液及び基質溶液を 0°C に保ちその酵素液の一定量をカゼイン反応液（pH5.2）に添加して一定時間 0°C に保つた後之に飽和度硫安溶液になるよう一定量の固形硫安を添加して濾過し，沈澱物を飽和度硫安溶液でよく洗滌した後其の濾液にトリクロール酢酸を添加して生ずる沈澱を硫酸分解に附し窒素量を測定した。同時に対照として酵素液及びカゼイン反応液を混合することなく一定の時間 0°C に放置した後夫々固形硫安を加えて飽和度となし，生ずる沈澱を別々に濾別した後両者の濾液を一緒にして之にトリクロール酢酸を添加して生ずる

※ 水産講習所研究業績 第224号，1957年7月25日 受理

沈澱を分解し其の窒素量を定量した。

Table 1. Formation of so-called symplex from protease and casein.

a)

Cooling period of mixture. (minutes)	8	13	18
Protein-N. in filtrate of mixture. (mg × 10^{-3})	4.47	4.23	8.55
Control : total protein-N. in filtrate obtained by filtrating independently casein and enzyme. (mg × 10^{-3})	10.65	11.01	11.28

b)

Cooling period of mixture. (minutes)	4	6	8	10	12
Protein-N. in filtrate of mixture. (mg × 10^{-3})	9.69	9.23	7.83	10.02	9.13
Control : total protein-N. in filtrate obtained by filtrating independently casein and enzyme. (mg × 10^{-3})	—	10.53	10.63	—	—

c)

Cooling period of mixture (minutes)	8	13	18
Protein-N. in filtrate of mixture (mg × 10^{-3})	4.31	6.85	7.78
Control : total protein-N. in filtrate obtained by filtrating independently casein and enzyme. (mg × 10^{-3})	9.18	8.85	9.04

以上の実験諸結果から 0°C の反応温度に於いては8分前後に於て沈澱生成量は極小値を示している。之に対し対照値は放置時間と関係なく大体一定値を示している。此のことからプロテアーゼ分子とカゼイン分子は混合された瞬間から酵素－基質－複合体を生じ始めるが約8分附近で最大量に達するもののようである。その後沈澱量が徐々に減少するのは複合体の分離速度が徐々に増してくるためであろう。而して各放置時間に於ける測定値が対照区の夫より少い値を示しているが、これは酵素分子がカゼイン分子と結合し或は接触するために微妙添加に際し沈澱性を増大することに依り逆に濾過性蛋白質は対照に比してより少くなるものと考えられる。濾紙は東洋濾紙株式会社製 No. 7 を使用した。この濾紙の濾過孔の大きさは厳密な意味での均一性を有していないのであるが多数の実験結果は常に上述の傾向を示しているのである。

総　　括

ピンノカ鮪幽門垂プロテアーゼ、井頁カゼインを0°Cに冷却した後混合して生じた所謂酵素－基質－複合体を捕捉することが出来た。複合体の生成量は混合後約8分附近に於て最大値を示した。本研究は農林省水産講習所後援会研究費によつたことを附記し感謝の意を表します。

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カゼイン及びビンナガ鮪幽門垂プロテアーゼに対する硫安の沈澱能について※

藤井　実・立川成章

Precipitation-power of Ammonium-sulfate against Casein and Protease-protein in Pyloric Appendage of Long Fin Tuna *Thunnus alalunga*

By

Minoru Fujii and Nariaki Tachikawa

We studied the precipitation-power of ammonium-sulfate against casein and protease-protein of pyloric appendage of long fin tuna.

Both were precipitated exceedingly well, when the pH of each reaction solution was ca. 5.2 at initial and then each solution was added with powder of ammonium-sulfate so as to attain 3/5—suturation-degree.

The protein-nitrogen precipitated by adding ammonium-sulfate of 3/5-saturation-degree to the enzyme solution was ca. 70 percent of the total protein-nitrogen precipitated by adding trichloro-acetic acid.

魚類幽門垂プロテアーゼの研究に於て其の基質として主にカゼインを使用しているので硫安が塩析剤として使用される場合カゼイン及び該酵素態蛋白に対して如何なる条件で最も良い沈澱能を発揮し得るかを知るため此の実験を行つた。

実　験　の　部

1）沈澱生成量と反応液のpHの関係

5％カゼイン液5ccに各種の pH 緩衝液（Mc Ilvaine 及び Clark a. Lubs の緩衝液）を夫々 32cc 宛添加して氷水で冷却した後，固形硫安を添加して½飽和度（Osborne に依る飽和度）とする。直ちに白色沈澱を生ずるので之を濾過し½飽和度硫安溶液で数回洗滌した後其の澄明な濾液に氷酢酸数滴及び20％三塩化酢酸液数cc（反応液中の三塩化酢酸が５％濃度になるように加える）添加すると夫々白濁を生ずる。これらの沈澱を濾別して始めと，三回同飽和度硫安溶液で，次に５％三塩化酢酸液で濾液にアンモニウムイオンの反応が消失する迄洗滌する。沈澱を硫酸分解に附し窒素量を測定した結果は第１表の通りである。尚酵素の抽出は常温で行うが其の他の場合溶液はすべて氷水で0°Cに冷却して使用した。

※ 水産講習所研究業績 第225号，1957年７月25日 受理

Table 1. Precipitation of casein under condition of various pH of reaction solution. Saturation-degree of $(NH_4)_2SO_4$: ½.

Initial pH	4	5.2	6	7	8.6
pH after adding $(NH_4)_2SO_4$	4.3	4.8	5.6	6.2	6.5
Protein-N. in filtrate mg×10⁻³ (2/100 of ppt.)	39.32	45.73	93.45	142.93	162.12

第1表の結果に依ると硫安添加前の反応液のpHが4である場合沈澱は最も多く次にpH5.2の順となり反応液がアルカリ性に近づくにつれ沈澱生成は著しく悪化することがわかる。而して始発pH4の場合カゼインは既に凝固するからカゼインにプロテアーゼを吸着させる目的からいえば此の状態では恐らく吸着不可能と考えられるから此のpHは目的に合わないわけである。従つて反応液の始発pHは5.2にして硫安を添加するのが最もよいようである。

2）硫安の飽和度の差異に依る沈澱生成量の相違

オスボン（Osborne）の表示法に従つて硫安の飽和度は⅓，½及び⅗にしたときのカゼインの沈澱状態を検討して第2表を得た。

Table 2. Precipitate of casein caused by adding ammonium-sulfate (saturation-degree : Osborne's degree).

Saturation-degree	⅓	½	⅗
Protein-N. in filtrate mg×10⁻³ (2/100 of ppt.)	64.04	53.04	47.67

此の実験結果からカゼインの沈澱は此の実験条件の範囲では⅗飽和度の場合が最も多いことがわかつた。

3）プロテアーゼ態蛋白の沈澱に対する硫安の影響

カゼインに対する硫安の条件をそのまま使つて反応液のpHを5.2にした酵素抽出液に固形硫安を添加して夫々の濃度を⅓，½及び⅗飽和度になるようにし，生じた沈澱を処理すること前述と全く同様にした後其の窒素量を測定して第3表の様な結果を得た。

Table 3. Precipitate of nitrogen-compound in enzyme solution caused by adding ammonium-sulfate and its proteolytic activity.

Saturation-degree	⅓	½	⅗	Control (non-adding)
Nitrogen content in precipitate from enzyme-solution, mg×10⁻³ (in 1cc of enzyme solution.)	1787.52	3330.21	4217.51	
Residual casein-N. after poteolytic action, mg×10⁻³(2/100 of ppt.)	3567.50	2405.10	1950.21	1852.52

第3表の示す通り硫安の濃度を増加するにつれて沈澱量も増大し此の実験の範囲では⅗飽和度で最大値を示した。又此等の沈澱をカゼインに作用させた時⅗飽和度の場合の沈澱が他

のいづれよりも強いカゼイン分解力を示した。従つて酵素態蛋白は3/5飽和度の時最も多く沈澱していることは明かである。

4）3/5飽和度硫安に依り沈澱する酵素態化合物の量

酵素抽出液に硫安を添加して3/5飽和度とした時に生ずる沈澱の窒素含有量を該酵素液に三塩化酢酸を添加して生ずる所謂蛋白態沈澱の窒素含有量に比較して第4表の様な結果を得た。

Table 4. Nitrogen content in compound precipitated by adding ammonium-sulfate of 3/5-saturation-degree and by adding trichloro acetic acid of 5 percent to the enzyme solution.

Precipitants	$(NH_4)_2SO_4$-(3/5-saturation-degree)	5 % trichloro acetic acid
$mg \times 10^{-3}$ / 1cc of enzyme solution	147.12	214.31

即ち上表の結果から3/5飽和度硫安に依る沈澱性窒素量は全蛋白態窒素の約70%程度であつた。

総　　括

カゼイン及びビンナガ鮪幽門垂プロテアーゼに対する硫安の沈澱能を検討した。反応液の始発 pH を約 5.2 とし之に夫々硫安を添加してその飽和度を1/3，1/2及び3/5とした場合，3/5飽和度の場合最も多量の沈澱を生ずる。そして鮪幽門垂プロテアーゼ溶液の場合硫安沈澱態窒素は全蛋白態窒素の約70%であつた。

本研究は農林所水産講習所後援会研究費によつたことを附記し感謝の意を表します。

魚類プロテアーゼに関する研究—VIII

ビンナガ鮪幽門垂プロテアーゼの酵素化学的性質—III

アセトン添加に依り該酵素溶液より生ずる沈澱量と其の蛋白分解酵素的作用※

藤　井　　実

Studies on the Protease of Fishes—VIII
On the Proteolytic and Chemical Properties of the Enzymes in Pyloric Appendage of Long Fin Tuna *Thunnus alalunga*—III
Precipitation of Protease-compound in Enzyme Solution Extracted from Powder of Pyloric Appendage of Long Fin Tuna by Adding Acetone of Various Concentration and Proteolytic Activity of that Precipitate

By

Minoru Fujii

By adding acetone of various concentration to the solution with proteolytic activity extracted from the powder of pyloric appendage of long fin tuna, nitrogen compounds in solution were graduated according to the range of acetone-concentration of each fraction;—40～50, 50～60 and 60～70%—; and the proteolytic activity and nitrogen content of each fraction were determined and resultes obtained are as follows:

Precipitates caused by acetone increase in proportion to the concentration of acetone, but the fraction of range of 50～60%—acetone is stronger in proteolytic activity per 1cc of enzyme solution and 1mg of nitrogen in precipitate than any other fraction.

前報告で明かな様に該鮪幽門垂より作られた蛋白分解酵素粗標品よりの水抽出液は強力なトリプシン様酵素力を示すが同液中には非酵素態蛋白及び非蛋白態窒素化合物を多量に含有している。従つて高単位の酵素力を有する純粋な酵素剤を得るためにはこれらを除去しなければならないのでその基礎実験として先づ酵素溶液に種々の条件下にアセトンを添加して沈澱を生成させた処，アセトンの濃度により其の沈澱生成量は異なり，且或るアセトン濃度分画区に於て蛋白態窒素 1mg 当りの蛋白分解酵素活力は最大になつた。

※水産講習所研究業績 第226号，1957年7月25日 受理

実 験 の 部

1）アセトン添加による沈澱生成量及びその蛋白分解酵素的作用力

酵素粗標品 0.5g に 20ccの燐酸緩衝液（Chlark a Lubs）を加えて1時間抽出を行つた酵素溶液3ccに一定量の蒸留水及びアセトンを加えてアセトン濃度を夫々30，50，60及び80%とすると沈澱を生ずる。同一濃度のアセトン液で数回洗滌した後沈澱を少量の pH7 の液にとかして基質カゼイン溶液に添加し全反応液を pH 8.5 に調製した後所定の如く反応させてその作用力を測定した，又同時に別に同一条件で作つた夫々の沈澱を硫酸分解して窒素量を測定し第1表の様な結果を得た。尚酵素の抽出は常温で行うがその後はすべての使用溶液を氷水につけて 0°C の条件で操作した。

Table 1. Nitrogen-content in enzyme solution precipitated with acetone of various concentration and its proteolytic activity.

Acetone concentration (%)	30	50	60	80
Nitrogen content in precipitate ($mg \times 10^{-3}$)	106.5	226.3	244.4	618.9
Proteolytic activity (Nitrogen-$mg \times 10^{-3}$) / 1cc of enzyme solution	2968.8	7673.3	9968.3	10288.3
Proteolytic activity (Nitrogen-mg) / 1mg of nitrogen	28.0	33.9	40.1	16.6

第1表の結果から次のことが判つた。アセトンの濃度が増大するにつれて酵素溶液よりの沈澱生成量（窒素量）も次第に増大し此の実験条件の範囲では約80%の場合最大を示した。そして沈澱物のカゼインに対する分解力も酵素液 1cc 当りの作用力は80%に於て最大であつた。しかるに窒素 1mg に対する作用力は逆に 60%附近が最もつよく 50%及び30%濃度の場合がこれにつづき80%の場合最低値を示した。以上のことから80%では酵素態及び非酵素態化合物が共に最も多く沈澱することを示すが，60%附近では非酵素態化合物の沈澱量は80%の場合に比べて少く且酵素態化合物の沈澱量に対する割合もより減少している。従つて窒素 1mg 当りの作用力は逆に最強を示すことになつたのであろう。

2）アセトンによる酵素態窒素化合物の分画

一定量の酵素溶液にアセトンを添加して30%となし此の時生じた沈澱の作用力及び窒素量を測定し次に此の沈澱を除去した濾液に更にアセトンを添加して全アセトン濃度を60%とし，生じる沈澱を前同様に処理し再びその濾液にアセトンを添加して80%とし生じた沈澱も前二者同様に処理して得た諸結果を示すと第2表の通りである。

第2表の結果から酵素液 1cc の酵素活力は30～60%分画が最も強く 60～80%分画はこれに次いで前者の約 80% の活性を示した。又窒素 1mg 当りの活性は30～60%分画が断然他区を引き離して高値を示した。一方一定沈澱量中の窒素量は 60～80% 分画最も多く 30～60% 分画は 0～30%分画と殆ど同じで 60～80% 分画の約 ¼～⅓ に過ぎない。以上の結果から酵素態化合物は 30～60% 分画に最も多く集つてくることは明らかで 60～80% 分画には非酵素態化合物が著し

Table 2. Nitrogen-content in enzyme solution precipitated with acetone of various concentration and its proteolytic activity.

Range of acetone concentration of each fraction (%)	0～30	30～60	60～80
Nitrogen content in precipitate ($mg \times 10^{-3}$)	105.7	114.7	509.5
Proteolytic activity (Nitrogen-$mg \times 10^{-3}$) / 1cc of enzyme solution	3398.8	11171.9	8638.6
Proteolytic activity (Nitrogen-mg) / 1mg of nitrogen	32.2	97.4	16.9

いことがわかる。従つて此の結果に基いて更に60%アセトン濃度を中心により詳細な分画実験を行つた。即ち更に細かく10%宛の差異を有する分画を行い夫々の作用力を検した。酵素試料(1.5g の粗標品に pH 8.5 の緩衝液 60cc を添加し抽出を行つたもの) 10cc を用い先づアセトン濃度を40%としその時生ずる沈澱を除去しその濾液にアセトンを添加して50%とし生ずる沈澱をカゼイン基質に添加すること上述の方法と全く同様にして夫々アセトン濃度40～50, 50～60 及び60～70%の分画を行い各区分に於ける沈澱の蛋白分解作用力を測定して第3表の様な結果を得た。

Table 3. Nitrogen-content in enzyme solution precipitated with acetone of various concentration and its proteolytic activity.

Range of acetone concentration of each fraction (%)	40～50	50～60	60～70
Nitrogen content in precipitate ($mg \times 10^{-3}$)	22.9	53.1	83.2
Proteolytic activity (Nitrogen-$mg \times 10^{-3}$) / 1cc of enzyme solution	1868.3	5352.3	5320.4
Proteolytic activity (Nitrogen-mg) / 1mg of nitrogen	84.6	100.8	63.9

即ち第3表の結果に依れば50～60%分画に於ける 1cc の作用力及び窒素 1mg 当りの作用力は共に他の分画の夫より大で特に窒素 1mg 当りの作用力は 100 に達した。又 1cc 当りの作用力は50～60%分画及び60～70%分画共に殆んど差異がなかつたが，沈澱性窒素量では60～70%分画が約60%以上も多いため 1mg 当りの作用力は逆に 50～60%分画に比べて60%以下に低下した。即ち50～60%分画に於ける窒素化合物は他区よりも酵素態化合物を豊富に含有していることは明かである。又40～50%分画に於ける沈澱性窒素量は他分画の夫に比べて最も少いにも拘らず，酵素態窒素化合物を比較的豊富に含有している。

総 括

ビンナガ鮪幽門垂粉末粗標品の水抽出液にアセトンを添加して種々のアセトン濃度溶液を作りプロテアーゼの分画試験を行い次の結果を得た。

1）アセトン添加による酵素抽出液よりの沈澱窒素生成物はアセトン濃度の増加に伴い増加し実験の範囲では80%で最高に達した。併し沈澱性窒素 1 mg 当りの作用力は 60%の場合最高値を示した。

2）更に各分画における沈澱性窒素生成物とプロテアーゼ作用力の関係を求めた所，50～60%分画に於いては酵素液 1cc 及び沈澱性窒素 1mg 当りの作用力は他の分画のいづれよりも大で窒素 1mg 当りの作用力は 100 に達した。又酵素液 1cc 当りの作用力は 50～60 %及び 60～70%両分画共に殆んど差異がなかつたが，60～70%分画では非酵素態窒素がはるかに多いために窒素 1 mg 当りの作用力は逆に 50～60%分画の 60%以下に低下した。又40～50%分画に於いては酵素液 1 cc 当りの作用力は他分画に比べて非常に低い値を示したが沈澱性窒素 1 mg 当りの作用力は50～60%分画のそれに次いでその80%以上に及ぶ値を示した。此の稿を終るに当り実験の 1 部を担当された立川成章君に深謝する。本研究は農林省水産講習所後援会研究費によつたことを附記し感謝の意を表します。（尚此の論文の大要は昭和31年 9 月の日本水産学会秋季大会（広島市）に於いて発表した。

魚類プロテアーゼに関する研究—IX

ビンナガ鮪幽門垂プロテアーゼの酵素化学的性質—IV

硫安添加に依り該酵素溶液より生ずる沈澱量と其の蛋白分解酵素的作用※

藤　井　　実

Studies on the Protease of Fishes—IX
On the Proteolytic and Chemical Properties of the Enzymes in Pyloric Appendage of Long Fin Tuna *Thunnus alalunga*—IV
Precipitation of Protease-compound in Enzyme Solution Extracted from Powder of Pyloric Appendage of Long Fin Tuna by Adding Ammonium-sulfate of Various Concentration and Proteolytic Activity of that Precipitate.

By

Minoru Fujii

By adding ammonium-sulfate of various concentration-degree of saturation : 1/3, 1/2 and 3/5 by Osborne's degree to the enzyme solution extracted from the powder of pyloric appendage of long fin tuna, we found the greater precipitation under condition of 3/5—saturation-degree than under that of any other degree and its proteolytic activity was ca. 95% of original activity or more.

Protease-activity was not inhibited at all, though precipitating of protease-compound was repeated by means of ammonium-sulfate.

硫安は酵素蛋白の塩析剤として古くから使用せられている。著者もプロテアーゼの精製を行う上にその塩析及び分離に該塩を使用する為の予備実験として硫安のプロテアーゼに対する諸影響を検討した。

実　験　の　部

1）　硫安添加に依る沈澱生成量及び其の蛋白分解酵素的作用力

著者等の研究[1]に依れば硫安に依るカゼインの塩析は反応液の pH を約5.2にした時に最も良い成績を示したのでプロテアーゼの塩析を行う反応液の pH はすべて5.2とした。硫安の飽和度はオスボーン（Osborne）の飽和度表示方式に従つて算出した硫安の固形量を酵素液に添加して生ずる沈澱を分離し数回同一濃度の硫安液で洗滌した後更に5％トリクロール酢酸液で

※ 水産講習所研究業績 第227号，1957年7月25日 受理

洗滌し，洗滌濾液にアンモニウムイオンの反応がなくなる迄洗滌を行う。然る後硫酸分解に附して窒素量を測定する。別に同時に全く同様な操作に依り生成させた沈澱をトリクロール酢酸液で洗滌することなく直ちに5%カゼイン5cc（或は10cc）を含む pH 8.5 の反応液に添加して40C° 1時間反応させて，反応後 20% トリクロール酢酸液一定量（混液のトリクロール酢酸濃度5%になる様にする）及び少量の氷酢酸を添加して酵素作用を止め，生じた未反応の蛋白沈澱物を5%トリクロール酢酸液で充分洗滌してアンモニウムイオンの反応の無くなつた後硫酸分解に附して窒素量を測定する。対照試験は硫安処理により生じた沈澱を熱処理して酵素活性を破壊した後反応液に添加して以下全く同様な操作を行つたものである。尚沈澱を作るまでの操作はすべて反応液を氷水で0°C近くに冷却して行つた。実験結果の1例を示すと第1表の通りである。

Table 1. Precipitate in enzyme solution by adding $(NH_4)_2SO_4$ of various concentration and its activity.

Saturation-degree of $(NH_4)_2SO_4$ (by OSBORNE's method)	1/5	1/2	3/5	None-adding (control)
Content of nitrogen in precipitate in 1cc of enzyme-solution ($mg \times 10^{-3}$)	865.0	927.8	1036.0	
Content of nitrogen in residual precipitate, coagulated by adding CCl_3COOH ($mg \times 10^{-3}$)	5546.5	3423.0	3236.5	3074.6

第1表の結果から此の実験の範囲では3/5飽和度に場合が沈澱生成物に窒素含有量最も多く又カゼインに対する該沈澱生成物のプロテアーゼ作用力も最強であることが明かとなつた。即ちプロテアーゼ態沈澱生成物は硫安の濃度増加と共に増大し3/5飽和では対照（硫安無処理）に約95%の作用力を示した。

2） 硫安沈澱（3/5飽和）の反復による酵素活性の失活の有無

pH 5.2にした酵素溶液に3/5飽和度になるように固形硫安を添加して沈澱を生ぜさせその沈澱を溶液より分離して再び pH 7 の緩衝液（Mc ILVAINE 氏緩衝液）に溶かして再び元の酵素液量として其の1部を用いて作用力及び蛋白態窒素量を測定する。残液に就いて再び同様な処置を繰返して沈澱を生成しそれを溶かして元の液量にして作用力及び蛋白態窒素量を測定すること上述と全く同様にする。これらの結果は第2表の通りである。尚実験に用いる溶液はす

Table 2. Repeating of precipitation by means of adding $(NH_4)_2SO_4$ and its activity.

	Original	1st. ppt.	2nd. ppt.
Content of nitrogen in 1cc-enzyme-sol. ($mg \times 10^{-3}$)	288.5	230.3	243.4
Relative proteolytic activity of 1cc of enzyme-sol.	313.5	307.9	308.7
Relative proteolytic activity of 1 mg of nitrogen.	1087	1337	1298

て氷水中に浸して0°C近くにしたものである。

第2表の結果に依ると硫安添加により酵素液中の窒素量は若干減少するが，1cc 当りの作用

力は殆んど原液の98%以上の作用力を保持し，1mg当りの作用力を比較すると処理した酵素液は原液に対し逆に作用力の上昇を示し第2回目の処理のものは第1回目のそれに比し殆んど作用力は劣らない。以上の事実から次の如く考えることが出来る。即ち硫安処理により非酵素態窒素化合物がかなり除去された結果1mg当りの作用力が上昇したものであり，且硫安はプロテアーゼに対し殆んど阻害作用を示さないということである。

総　　括

pH を約5.2にしてプロテアーゼ溶液に硫安を添加してその飽和度を夫々⅓，½及び⅗とした所謂飽和度で最も多量の沈澱性窒素化合物を生じ且その酵素活性も最強で原酵素活力の約95%或はそれ以上を保持した。又硫安塩析を繰返したが酵素活性は殆んど減少を示さなかつた。即ち硫安はプロテアーゼに対し阻害作用を殆んど示さない。

此の論文の大要は昭和31年9月の日本水産学会秋季大会（於広島市）に於いて発表した。尚分析を分担された西野イチ氏に深謝する。本研究は農林省水産講習所後援会研究費によつたことを附記し感謝の意を表します。

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マグロ罐詰に関する研究—I

フレーク味付罐詰の成分に就いて※

河内正通・江良至徳

Studies on the Canned Tuna — I
Determination of Various Components in Canned Tuna

By

Masayuki Kōchi and Shitoku Era

We have determined general components, inorganic components and vitamin A in canned flakes of white meat tuna (seasoned), and examined the nutritive values. The results are as follows:—

1) Protein and fat occupy by far the greater part of the component of tuna flesh and, as the flesh is a seasoned one, a greater deal of non-reducing sugar and ashes has been found to be in it than in the ordinary flesh.

2) Being a seasoned one, the flesh is mainly composed of NaCl, as is the case with any other seasoned one, and besides NaCl are found in it Ca, Mg, P_2O_5, Fe and Al in varying degrees.

3) As to micro-inorganic components, Mn, Cu, Zn and Co have been found in the flesh except I_2.

4) Vitamin A has not been found in the body fat of the canned meat.

5) Calories of the canned contents are 220.83 cal. per 100g., the values of which are not inferior to those of animal meat, such as beef, but the flesh is exceedingly rich in nutritive values.

緒　　言

マグロ類罐詰の成分に関しては，この水産業に於いて占める地位の重要性からして，古くから多数の人々によつて研究されているが，いづれも輸出を対象としたフアンシー油漬，又は塩水漬罐詰に就いてであり，国内で販売されている フレーク味付罐詰に就いての研究は殆んど見当らない。

最近，罐詰類も漸く栄養食品として注目される様になり，国内に於ける需要も年々増加の一途を辿つている。而してこれら罐詰中でもマグロ類フレーク味付罐詰の消費は著しく，この正常なる発展の上からも栄養的価値の裏付けが緊要であると考え，フレーク味付罐詰を製造し，

※ 水産講習所研究業績 第228号，1957年7月25日 受理

その一般成分，無機成分，一部の微量成分及びビタミンA等を定量したので茲にその結果を報告する。

実験方法

試料　石巻港に水揚された第1表の如き鮮度良好なビンナガマグロ *Thunnus alalunga* (BONNATERRE) を原料として，常法に従つて罐詰を製造した。その主要工程の処理条件及び測定結果を第2表に示す。

Table 1. Organoleptic examinations and various measurements of raw material tuna.

Synthetic * judgment	Eyes	Skin colour	Gill	Internal organs	Back elasticity	Abdominal elasticity
85	a′	a	a′	a	a	a′

Total length (L) (cm.)	Body weight (W) (kg.)	Weight after removed head and organs (kg.)	Corpulent degree ($W/L^3 \times 1000$)	Fatty ** Coefficient (W/W_0)	Moisture (%)	Volatile basic-N (mg. %)
75.8	11.625	8.938	0.0267	11.121	67.5	28.9

* It is showed that best is 100.
** Body weight (W)/body weight in water (W_0)

Table 2. Various measurements of cooked tuna and conditions of canning process.

Cooking			After cooking		
Preparation heating (min.)	Pressure (lb.)	Time (min.)	Weight (kg.)	Moisture (%)	Volatile basic-N (mg. %)
60	2	200	8.063	62.0	21.0

Date of canning	Can size	Preparation heating (min.)	Pressure (lb.)	Time (min.)
Aug. 25,1950	No. 6	15	8	70

この罐詰を約2ケ月間貯蔵したる後，開罐し水浴上で加熱乾燥して供試用貯蔵試料を調製した。その結果を第3表に示す。

Table 3. Test of can and preparation of dried meat.

Date of open the can	Can vacuum (inch)	Net weight (g.)	Evaporated moisture in drying process (%)	Dried meat (sample meat) (%)
Nov. 2,1950	11	196.1	56.50	43.50

定量法　一般成分は常法，無機成分は塩基性酢酸鉛法[1]，非還元糖は塩酸で加水分解後 LEHMANN-MAQUENNE-SCHOORL'S 法[2]，銅は Dithizon-CCl_4 による抽出定量法[3] によつた。

結果及び考察

一般成分の分析結果は第4表に示す通りで，脂肪含有量が比較的少ないのは所謂「夏マグロ」であるためと思われ，非還元糖及び灰分が多いのは味付罐詰であるためその大部分が注加された調味液に由来するものと考察される。そしてこの罐詰肉100g当りの熱量は220.83カロリーで，安藤[4]が多数の獣肉に就いて研究した結果と比較して決して劣らず，兎角，栄養的に軽視されていたこれら罐詰食品の価値を再認識すべきだと考える。

Table 4. General components of canned tuna.

	g. per 100g. canned meat	g. per 100g. dry matter
Moisture	59.19	0
Total-N	3.00	7.35
Crude protein	18.78	45.94
Crude fat	14.77	36.20
Non-reducing sugar	1.58	3.87
Ash	3.54	8.67
Vitamin A	0	0
Calorie	220.83 cal.	

亦，この灰分中の無機成分を分析した結果は第5表の通りで，食塩がその過半量に達しているが，これは前記の如く注加した調味液に由来するためと推定され，このため他の無機成分の含有量の割合が相対的に減少しているが，カルシウム，マグネシウム，燐酸等は奥田[5]がカツオに就いて分析した結果と大差は認められない。鉄，アルミニウムも相当量に達し，特に鉄は多量に存在したが，この一部は罐材及び食塩に由来するものと考えられる。

Table 5. Inorganic components of canned tuna.

	g. per 100g. canned meat	g. per 100g. ash
NaCl	2.23	62.99
SO_3	0.004	0.11
Sand	0.32	9.12
CaO	0.09	2.51
MgO	0.08	2.35
P_2O_5	0.33	9.29
Fe_2O_3	0.24	6.81
Al_2O_3	0.13	3.56
Mn_3O_4	0.009	0.25
Cu	0.004	0.11
Zn	Confirmed	Qualitative analysis
Co	〃	〃
I_2	Uncertain	〃

この外，最近栄養学的にも微量成分として注目されているマンガン，銅，コバルト等[6]も含有していることを確認したが沃素の存在は確認出来なかつた。沃素の含有量は[5][7][8]は魚種によつて著しく異なり，一般に魚肉1kg中に20γ乃至1000γ，マグロ罐詰肉中には300γ程度含有されているといはれていることから，試料採取量が未だ僅少に過ぎたために確認出来なかつたものとも思考される。亦ビタミンAは魚類肝油中に多量に含有されることは言を俟たないが，体脂肪中には殆んど存在しないか，存在しても極く微量であるという報告[9]があるが，この実験の結果からもその存在は全然認め得なかつた。

総　括

フレーク味付罐詰の成分を分析し，次の結果を得た。

1）　その発熱量は牛肉，その他の獣肉に比較し決して劣らず，栄養価の高いことが判明した。

2）　無機成分も栄養的に重要なものが多量に含有され，一部微量成分も含有することを確認した。

3）　罐詰肉脂肪中にはビタミンAは含有されないことが判明した。

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マグロ罐詰に関する研究—II

液汁のpH測定に就いて※

河内正通・江良至徳

Studies on the Canned Tuna — II

On the pH Determination of Canned Tuna Liquids

By

Masayuki KŌCHI and Shitoku ERA

We determined the pH values of canned fancy white meat tuna liquids by both quinhydrone and antimony electrodes, as the result of which it was found that pH values changed with the lapse of time.

Therefore, we made the comparative study of the determining methods and the errors by using glass electrode as well as the pursuit of the changeable cause of the pH values.

The results are as follows : —

1) The cause of pH changes as determined by quinhydrone and antimony electrodes is protein error mainly due to soluble protein, and when the protein concentration is decreased with diluted liquids by distilled water, the errors due to oxidizing or reducing matter come out gradually as the opposite ones.

2) When it is diluted about 6 times in quinhydrone electrode or 14 times in antimony electrode by distilled water, we can obtain the stable pH by counter-balancing their errors.

3) In the above-mentioned methods, quinhydone electrode has enabled us to determine the pH with an error of 0.1 pH, but antimony electrode makes it difficult for us to obtain the correct pH, accompanied by many errors.

We have had tuna flesh canned, using the flesh of different degrees of freshness, and investigated the relation between the freshness and pH values by means of quinhydrone, antimony and glass electrodes.

The results are as follows : —

1) It is difficult for us to find the relation between the freshness and pH values, but in the case of blue meat it has apparently higher pH value than the rest.

2) When the liquid 6 times diluted is determined by quinhydrone electrode,

※ 水産講習所研究業績 第229号, 1957年7月25日 受理

it is possible for us to judge the freshness of the tuna flesh from the pH vlalue.

3) It is impossible for us to find the relation between the freshness and pH values, when it is determined by antimony electrode.

緒 言

マグロ鮮肉の pH に関しては河端等[1]がガラス電極を用いて詳細に研究し，魚体部位により忽しく差異のあることを指摘している。亦，山中[2]は土壌の pH を各種の電極で測定，比較し酸化還元系電極では溶存する鉄イオンの影響によつて正確な値を示さないと報告している。以前，江良[3]は罐詰肉の品質判定の手段として，その肉汁の pH を測定する方法を提唱し，pH 6.0以下のものは品質良好で，6.3以上のものは肉色は青味を帯び風味悪く，悪臭が強いと報告した。しかしながら，この測定にはアンチモン電極を使用したため種々なる物質に基づく誤差が考えられ真の pH を示していたかどうか疑問で，以上の事実は寧ろアンチモン電極の現わす電位差（pH）と品質との間に何等かの相関があるものと推測するのが妥当の様である。鯵坂等[4]は同様にマグロ油漬罐詰の品位と魚肉 pH との関係をキンヒドロン電極で測定し，品位と pH の間には一定した関係は見られないと報告している。

これら品質と pH との関係を，なお詳細に追試するためこの実験を実施したが，キンヒドロン及びアンチモン電極では測定中経時的にその電位差が変化し，安定した値を得ることが出来なかつた。そのためこの様な経時変化が如何なる物質に起因するものであるかを検討すると共にその測定方法を研究した。

然る後，原料鮮度の異なる罐詰液汁の pH をこれら電極で測定すると共にガラス電極でも測定，比較し品質と pH の関係を究明した。

実 験 方 法

試 料 石巻港に水揚げされた第1表のような夫々鮮度の異なるビンナガマグロ *Thunnus*

Table 1. Organoleptic examinations and various measurements of raw material tuna.

No	Synthetic* judgment	Eyes	Skin colour	Gill	Internal organs	Back elasticity	Abdominal elasticity
1	85	a′	a	a′	a	a	a′
2	75	a′ — b	a′	a′ — b	a	a	a′ — b
3	65	b — c	b	b	a′	a′ — b	a′ — b

No	Total lenght (L) (cm.)	Body weight (W) (kg.)	Fatty ** coefficient (W/W_0)	Corpulent degree ($W/L^3 \times 1000$)	Moisture (%)	Volatile basic-N (mg. %)
1	75.8	11.625	11.121	0.0267	67.5	28.9
2	75.9	12.281	10.01	0.0280	67.0	20.8
3	75.6	10.875	10.01	0.0251	69.0	25.1

* It is showed that best is 100.

** Body weight (W)/body weight in water (W_0)

alalunga (BONNATERRE) を原料として，常法に従つてフアンシー水煮罐詰を製造した。その主要工程に於ける処理条件及び測定結果を第2表に示す。

Table 2. Various measurements of cooked tuna and conditions of the canning process.

No	Cooking			After cooking		
	Preparation heating (min.)	Pressure (lb.)	Time (min.)	Weight (kg.)	Moisture (%)	Volatile basic-N (mg. %)
1	60	2	200	8.063	62.0	21.0
2			205	8.025	61.0	29.5
3			160	6.900	64.0	32.3

No	Can size	Packing weight			Sterilization		
		Meat (g.)	Water (g.)	Net weight (g.)	Preparation heating (min.)	Pressure (lb.)	Time (min.)
1 2 3	Tuna No.2	167	36	203	15	8	70

この罐詰を開罐後内容物をガーゼにて包み，指頭で軽く圧搾し，流出した肉汁を採取して供試液とした。

使用電極

ガラス電極[5] 真空管UX—54を使用した直流増巾方式。精度 0.02pH

キンヒドロン電極[6] 島津製3P型電位差計を使用し，その電位差より pH を算出した。精度 0.01pH

アンチモン電極[6] 島津製3P型電位差計を使用し，予め pH 既知の数個の緩衝液について測定し，pH —電位差直線を求め，この直線式より，測定電位差に相当する pH を算出した。精度 0.1 pH

以上いづれの電極も対極としては飽和甘汞電極を用いた。

結果及び考察

〔I〕 キンヒドロン電極による測定

近年ガラス電極の急速な発達によつて食品類の pH 測定も非常に容易となつたが未だ，高価で一般に普及するに至つて居らない。

キンヒドロン電極は電極の作製の操作が簡単で短時間に測定でき而もその精度が高い等の多数の利点があり，一般に賞用されているが他方，アルカリ性溶液や蛋白質，塩類及び酸化還元性物質を含む溶液では，それらによる誤差を伴うため，正確な pH 測定が出来ないという欠点があり従来，食品類には殆んど使用されて居らなかつた。

斯様な電極を用いて罐詰液汁の pH 測定ができ而も品質判定の手段として用い得るならば非常に便利であると考え，測定を実施した処，その pH は時間と共に変化し一定した値を得ることが出来なかつた。この誤差の原因を究明するために次の実験を実施した。

即ち液汁を直接測定した処，第1図（a）の様に，その pH は非常に経時変化を示し，この液汁に種々なる割合に食塩水を加え溶存する蛋白濃度を減少せしめた処，夫々（b），（c）及び（d）の如くその変化が緩慢となつた。そして液汁中に多量のキンヒドロン粉末を加え，その粉末中に白金電極を埋没して測定すれば夫々（a'），（b'）の如く同一溶液でも変化の度合が少なくなり（b'）では殆んど変化を認めなかつた。

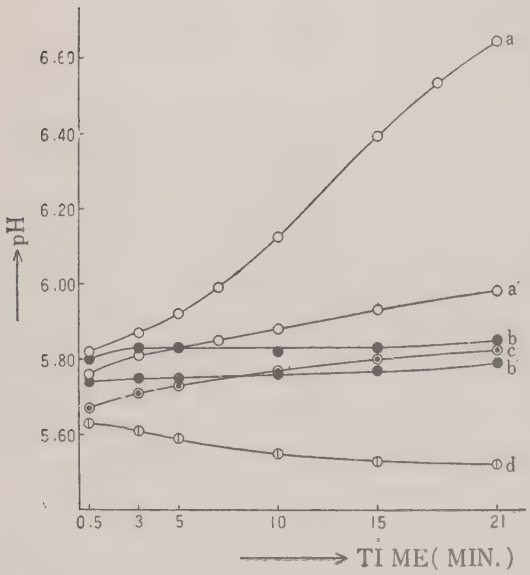

Fig. 1. Influence of sodium chloride solution on pH changes as determined by quinhydrone electrode.
a) Canned tuna liquids.
a') Canned tuna liquids, add a large quantity of quinhydrone.
b) Canned tuna liquids 1.0% NaCl ratio 1:1.
b') Canned tuna liquids 1.0% NaCl ratio 1:1, add a large quantity of quinhydrone.
c) Canned tuna liquids 0.5% NaCl ratio 1:1.
d) Canned tuna liquids 20% NaCl ratio 1:20.

以上の実験から吉村[6]が述べていると同様にその経時変化の最大原因は，液汁中に溶存する蛋白質に基づくもので，キノンと蛋白質との反応の結果溶液中の〔キノン〕／〔ハイドロキノン〕の比が減少し，その電位差が次第に下降（pH は上昇）するものと推定される。

而してキンヒドロンを多量に加えれば変化の度合が少ないことから，今後の実験はすべて，この様にして実施した。

次に前と同様な液汁を蒸溜水にて種々な割合に稀釈して測定し，第2図の結果を得た。即ち6倍に稀釈（c）すれば殆んど変化なく，これを境界として，それ以下の場合（a'）及び（b）は次第にアルカリ性側に，それ以上の場合（d）及び（e）は逆に酸性側に変化した。これは稀釈による緩衝力の低下によつて空気中の酸素の影響が現われるためと考えるよりも寧ろ，蛋白濃度の減少に伴い液汁中に溶存する酸化還元性物質等の溶解量の増大，キンヒドロン或はキノン，ハイドロキノン等と化学反応を起す結果，逆の現象が現われるためと推測され，丁度6倍に稀釈した場合には蛋白誤差とこれらの誤差が相殺し，恰も外観上は変化を示さない様に見えるものと考へられる。

〔II〕　アンチモン電極による測定

従来，特殊な酸化被膜を施した直読式アンチモン電極が簡易 pH 計の名の下に発売され食品関係の pH 測定にもかなり使用されていたが，これも酸化還元系電極であるため，キンヒドロン電極と同様な誤差を伴うことは勿論で，その他，アンチモン棹それ自体の性質からしてさして再現性に富むものではない等の理由から，食品の pH 計測に使用される場合どの程度信頼性のあるものか疑問であつた。

この信頼性を試験するため，先づ前記同様な液汁の pH を測定し，第3図（a）の如き忽し

い経時変化を認めた。そして前記同様この液汁を蒸溜水にて種々な割合に稀釈して測定し夫々（b），（c）及び（d）を得た。即ちこの場合は14倍程度の稀釈により殆んど変化を認めず，これを境界として変化の方向が逆転した。

〔III〕 キンヒドロン電極とアンチモン電極の pH の比較及び原料鮮度と pH

前記の如くして製造した原料鮮度の異なる罐詰液汁の pH を夫々キンヒドロン電極，アンチモン電極を用いて測定し，第4図の結果を得た。即ち一般に電位差の平衡に達するに要する時間はキンヒドロン電極では30秒，アンチモン電極では，3～5分であることより夫々その値を互に比較すると，0.45

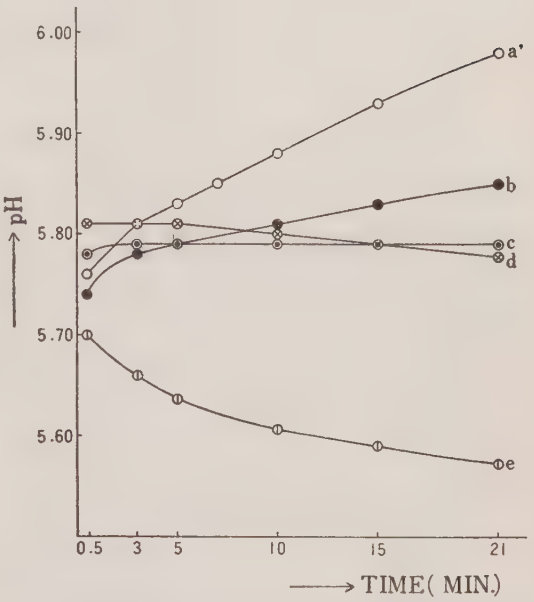

Fig. 2. Influence of the dilution with distilled water on pH changes as determined by quinhydrone electrode.
a′) See Fig. 1.
b) Canned tuna liquids water ratio 1 : 1.
c) Canned tuna liquids water ratio 1 : 5.
d) Canned tuna liquids water ratio 1 : 9.
e) Canned tuna liquids water ratio 1 : 49.

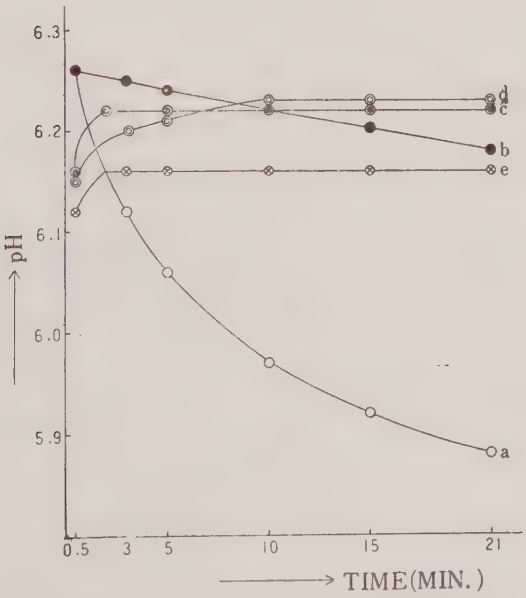

Fig. 3. Influence of the dilution with distilled water on pH changes as determined by antimony electrode.
a) Canned tuna liquids.
b) Canned tuna liquids water ratio 1 : 5.
c) Canned tuna liquids water ratio 1 : 13.
d) Canned tuna liquids water ratio 1 : 14.
e) Canned tuna liquids water ratio 1 : 49.

pH 程度の差があることが判明した。そしてその経時変化の割合は，21分後に於いて，キンヒドロン電極では夫々1.72，0.48，1.20 pH と非常に大であるのに対し，アンチモン電極では夫々0.37，0.07，0.07と比較的小であつた。これは殆んどアンチモン電極棹自体の性質に基づく経時変化の範囲内に止まつており，無視し得ることから，その pH 精度は別問題として，品質との間に何等かの相関が見出せれば，キンヒドロン電極を使用するよりも寧ろより容易に品質判定の手段として使用出来るものと推定されるが，この実験からは両電極共に特別な関係は認め得なかつた。

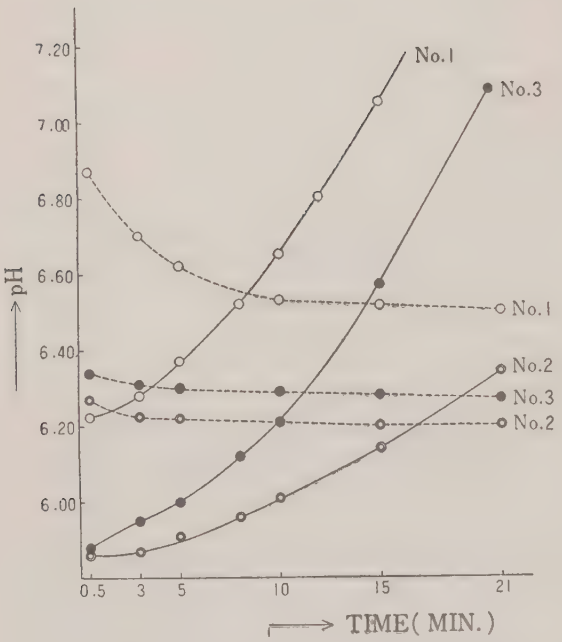

Fig. 4. Comparison of pH values as determined by quinhydrone and antimony electrodes, and relation between freshness and pH values.
—— Quinhydrone electrode.
····· Antimony electrode.

〔IV〕 ガラス電極とキンヒドロン電極の pH の比較及び原料鮮度と pH

前記同様な原料で同時に製造した他の罐詰液汁の pH をガラス電極，キンヒドロン電極で測定し，第3表の結果を得た。

即ちキンヒドロン電極で測定する場合はキンヒドロン粉末を添加後30秒（飽和直後）の値が最も真の pH に近い値を示し，0.01～0.06 pH の範囲で一致することが判明した。

亦，蒸溜水で6倍に稀釈した液について測定し一定となつた値をとれば0.02～0.12 pH 程度の誤差で精測出来ることが判明した。

次に原料鮮度とガラス電極で測定した pH との間には特別な関係は認められなかつたが，只，青肉では明らかに高い値を示した。

亦，キンヒドロン電極で直接液汁

Table 3. Comparison of pH values as determined by quinhydrone and glass electrodes, and relation between freshness and pH values.

No. \ min.	Glass electrode	Quinhydrone electrode					
	—	0.5	1	5	10	15	21
1	6.05	6.06	6.09	6.07	6.10	6.11	6.13
1′	5.98	—	5.88	6.00	6.02	6.03	6.03
2	6.06	6.12	6.18	6.22	6.23	6.26	6.27
2′	6.11	6.11	6.09	6.08	6.11	6.11	6.11
3	6.03	6.08	6.12	6.19	6.20	6.20	6.23
3′	6.01	—	6.13	6.13	6.13	6.13	6.13
B	6.28	—	—	—	—	—	—
B′	6.82	6.08	6.27	6.38	6.40	6.40	6.40

B : Blue meat. ′ : Canned tuna liquids water ratio 1 : 5

の pH を測定した値との間にも何等関係を認めなかつたが6倍に稀釈した液汁では夫々6.03, 6.11, 6.13及び青肉では6.40と鮮度が悪くなるに従つて，次第に高い値を示し，この一定となつた値と原液をガラス電極で測定した値との差は夫々−0.02, 0.05, 0.10, 0.12 pH と鮮度良好なものでは負であるのに対し，鮮度が悪くなるに従つて次第に正の値が高くなつた。

以上の実験から，その液汁のpHをガラス電極で測定すると共にその6倍稀釈液についてキンヒドロン電極で測定すれば原料鮮度の推定が或る程度可能であると判断される。

総　　括

ビンナガマグロ水煮罐詰液汁のpHを各種電極を用いて測定し，次の結果を得た。

1. ガラス電極で原料鮮度の異なる罐詰液汁のpHを測定した結果，原料鮮度とpHの間には特別な関係は認めなかつたが青肉は明らかに高い値を示した。
2. 罐詰液汁の緩衝力は比較的弱く，6倍程度の稀釈でかなりのpHの変動を示した。
3. キンヒドロン電極及びアンチモン電極の経時変化の原因は主として蛋白質と推定され，稀釈すれば次第に他の誤差が現われ，夫々6倍，14倍程度の稀釈で，これらの誤差が相殺して外観上は変化を示さず，安定したpHを与える。
4. キンヒドロン電極では6倍稀釈液で測定し，その一定した値をとれば0.1 pH程度の誤差で精測することができ，この値から原料鮮度が推定出来る。
5. アンチモン電極では最初から0.4～0.6 pH程度の誤差があるものと推測され，この値と原料鮮度との間には，この実験からは特別なる関係は認めなかつた。

以上少数例の実験結果のみで断定し兼ねるが尚今後実験を続ける所存である。

終りに試料罐詰を贈与下さつた日本罐詰検査協会清水検査所の方々及び実験上有益な御指導，御助言を賜つた九州大学農学部農芸化学科古谷貞治先生に深甚なる謝意を表す。

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E. coli の硝酸塩還元作用による Aureomycin の定量※

中　野　道　紀

Quantitative Analysis of Aureomycin by the Nitrate Reducing Action of *E. coli*

By

Michinori NAKANO

It was Goth, Bush (1944) who investigated the method determing quantiative analysis of penicillin by means of the suspension of *staphylscoccus*. Subsequently Nielson, Foter (1946) also described the method determining quantitative analysis of antibiotics with the suspension of *E. coli*.

On the other hand the author has recoginized that it is possible to determine the method of quantitative analysis of aureomycin by the electric colorimetric method of nitrite which was reduced from *E. coli TYCC* 9637 after its cultivation of 37°C24 hours in nitrate media. The results obtained are as follows:

1. The author made the suspension of *E. coli* with nitrate media, and putting some of it a large test-tube, added to it aureomycin solution of the concentration, and determined nitrite which had been reduced from *E. coli* after the cultivation of 37°C24 hours by the colorimetric method.

2. $KNO_3 \cdot C_2H_5OH$ media has been found suitable for the analysis of nitrite.

3. When *E. coli* within 10^5—10^9/ml was inoculated into $KNO_3 \cdot C_2H_5OH$ media, nitrite reduced from *E. coli* enabled us to determine by means of the dilution of suitable concentration.

4. Nitrite which had been reduced from *E. coli* after the cultivation of 37°C24 hours in $KNO_3 \cdot C_2H_5OH$ media, was 1.85×10^{-8} μg per one *E. coli* inoculated, and it decreased to 1.68×10^{-9} μg in the same media containing 100μg aureomycin. This was 1/10 lower as compered with the former.

Aureomycin は比色法[1] 又は Bioassay[2] により定量される。

著者は *E. coli* の硝酸塩還元作用を利用して，この定量を試みた。

GOTH, BUSH (1944)[3] は *Staphylococcus* の浮游液を使つて Penicillin の定量を行い又 NIELSON, FOTER (1946)[4] は *E. coli* を使つて抗生物質を定量する方法を述べているが，著者は *E. coli* を24時間培養した後，その生成亜硝酸塩の比色定量から Aureomycin の定量が可能であることを知つたので報告する。

※水産講習所研究業績 第230号，1957年7月25日 受理

使用菌株：*E. coli TYCC* 9637

実 験 方 法

A 測定前の *E. coli* の培養

M/10 燐酸塩緩衝液にて 4～5 回遠沈洗滌（4000rpm）した後，冷蔵庫に貯蔵した *E. coli* の適量（10^4～10^9/ml）を含む懸濁液を作り，その18ml 宛を大試験管に分注し，これに各濃度のAM溶液2ml を加えて，培地のAM 濃度を夫々2.5, 25, 50, 75, 100μg としたもの及びAMを含まぬ培地2mlを加えたものを対照として，37°C24時間培養した後，直ちに氷冷し，10分後 Amberlite IR—120小量を加えて充分振盪し，4000rpm20分遠沈した後，その上澄10ml（濃度の濃すぎる時及び薄い時は適量）を共栓試験管にとり，亜硝酸塩の定量に供した。

E.coli 接 種 量

上記方法により *E. coli* の接種量を変えて37°C24時間培養した後，下記測定法に従い硝酸塩還元による生成亜硝酸塩を定量して，その適量を決めた。結果は第1表に示す如く接種量が多ければ透過率は2.0を示し，少い時は定量出来なかつた，この適量は培地 20mlに対し 4～8 mg (wet)（10^5～10^9/ml）である。

Teble 1. Relation between the concentration of *E. coli* TYCC 9637 and transmittance of nitrite reduced from nitrate after cultivation of 37°C 24 hours.

E. coli Concentration		Transmittance
mg/20ml (wet)	No./ml	of nitrite (%)
4	1.5×10^4	46.7
6	—	24.0
8	2.7×10^9	2.0

培 地

次に示す a）・b）の培地について夫々 *E. coli* 懸濁液として，その18mlに各使用濃度のAM溶液 2ml を加えたもの及び対照とについて 37°C24 時間培養後，その生成亜硝酸塩を比色定量して決めた。

a) $NaNO_3$・Glucose Media

第2表に示す培地は亜硝酸塩の定量に操作が複雑で不適当とした。

Table 2. Composition of $NaNO_3$・Glucose Media.

Components	Amount
$NaNO_3$	0.2
P-amiobenzoic acid	0.5
$CaCl_2\cdot6H_2O$	0.5
Glucose	10
M/10 phosphate buffer solution (pH 6.47)	100 (ml)

Diluted with CO_2 free distilled water to 1000 ml finally.

Table 3. Composition of KNO_6・C_2H_5OH Media.

Components	Amount
K_2HPO_4	0.5
KNO_3	10.
C_2H_5OH	5. (ml)
M/10 phosphate buffer solution (pH 6.47)	100. (ml)

Diluted with CO_2 free distilled water to 1000 ml finally.

b) KNO_3・C_2H_5OH Media

第3表に示す培地は *E. coli* を接種して 37°C24 時間培養後の亜硝酸塩生成量が多く，その生成亜硝酸塩を光電比色定量する場合，その値が比較的安定であることを認めたのでこの培地を使用することにした。

B 光電比色計による亜硝酸塩の定量

測 定 法

Griess が考案の Ilosvary, Lunge 法によつて行つた。即ち試料10mlにM/10燐酸塩酸緩衝液（pH 6.47）10ml を加えて更に GR 試薬約 0.2g を入れて 5 分間振盪した後，20°C の水槽に 5 分間浸漬して測定した。（室温20°C位時は 30～60秒振盪して可及的迅速に測定した。）測定値は 1 ～10分の最も安定した透過率を採つた。室温20°C内外では 5 ～ 9 分が適当であつた。

検量線は精秤せる $NaNO_2$ を蒸溜水にとかして NO_2 態N量0.1mg/ml のものを原液とし，蒸溜水で NO_2態Nを 1μg/ml～0.1μg/ml としたもの，及 $KNO_3 \cdot C_2H_5OH$ 培地にて NO_2 態N 1 μg/ml～0.1μg/ml としたものについてその透過率より作成した。この場合，蒸溜水にて調製したものは，その10ml 及 M/10燐酸緩衝液（pH 6.47 10ml を加えた。$KNO_3 \cdot C_2H_5OH$ 培地にて調製した場合はこの 10ml に AM 100μg の溶液 1 ml を加え更に M/10 燐酸緩衝液（pH 6.47）9ml を加えた。

AM による黄色着色は培地に対しその濃度 100μg の場合でも亜硝酸塩定量にあまり影響せず，AMの濃度差による着色差は亜硝酸塩定量に差支えないことを確めた。

検量線は第 1 図に示した。

試　　薬

a）Griess Reagent (GR)

次の組成からなるもので，これは充分注意して粉末とした後褐色瓶に貯蔵した。

α—naphthylamine 1.0g, sulphanylic acid 10.3g, tartaric acid 89.2g

b）Aureomycin Solution (AM)

AM は武田製薬オウレオマイシン（九大富山研究室分析値94%）0.100g を蒸溜水100 ml にとかして，冷蔵庫に貯蔵し，培養時使用濃度に希釈して培地18ml に対し2mlを加えた。これは其の都度調製した。

実 験 結 果

1）検量線は上記方法により第 1 図を得た。

この場合蒸溜水にて作成したものと $KNO_3 \cdot C_2H_5OH$ 培地にて作成したものはその値に差が認められたが完全に平行した。

後者が透過率が小さく，測定時比較的安定であつた。

AM 濃度差による着色の影響は殆んど認められなかつた

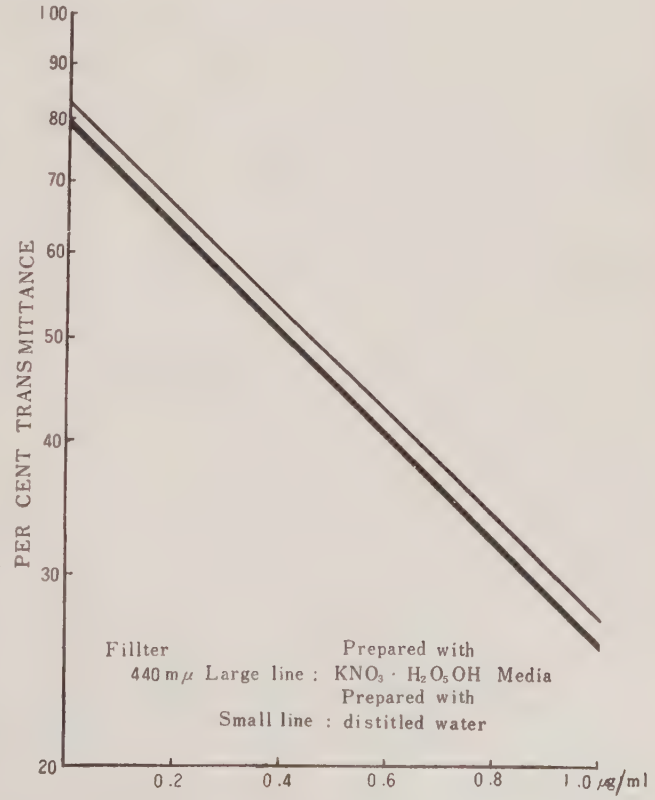

Fig. 1. Relationship between quontity of $NaNO_2$ and transmittance.

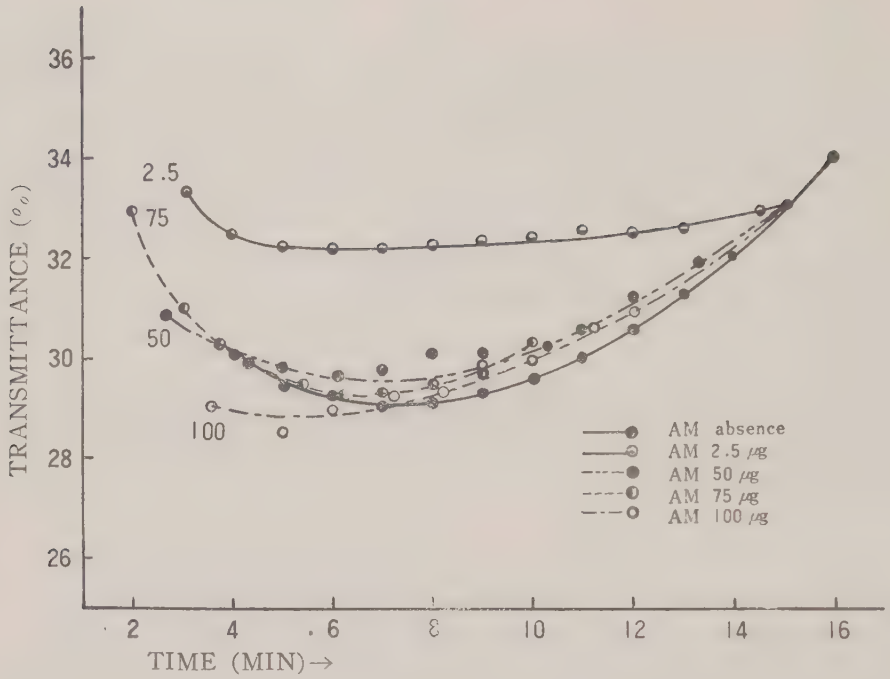

Fig. 2. Comparative transmittance change after adding the Griess reagent due to the different aureomycin concentration.

GR投入后5～9分の透過率が小さく安定した値を示した。即第2図の如くである。

2) *E. coli* TYCC 9637 の硝酸塩還元作用による AM の定量

実験の方法は前記A及Bに従つて行つた。

今,最初の *E. coli* 接種量を 30mg/100ml とした培地を 18ml 宛分注し，AM 濃度を100μg・50μg・25μg・2.5μg とした場合について，この方法を検討してみよう。

この場合，遠沈した上澄 0.2ml をとり定量し，第4表に示す結果を得た。

Table 4. Transmittance change of nitrite reduced from *E. coli* TYCC 9637 after cultivation of 37°C 24 hours in different aureomycin concentration of media.

AM Concns. (μg/ml) \ Times	1	2	3	4	5
2.5	28.0	28.2	28.0	28.0	28.0
25	30.4	30.2	30.2	30.2	30.2
50	37.0	37.0	37.2	37.0	37.0
100	48.2	48.2	48.0	48.0	48.0
absence	26.0	26.0	26.2	26.0	26.0

この値から *E. coli* TYCC 9637 の 37°C24 時間培養による亜硝酸塩生成量は第1図を用いて次の如く計算出来る。

E. coli 培養液 0.2ml中の NO_2 態Nは第1図にて 1.0μg/ml に当る。この検量線は $KNO \cdot C_2H_5OH$ 培地にて作成してあるから，この培養液中の亜硝酸態N量は 50μg/ml に当る。この培養時の菌数は 2.7×10^9/ml (培養時，普通寒天平板培養した)である故 菌1個あたりの亜硝酸態N生成量は 50μg/2.7×10^9/24hrs$=1.85\times10^{-8}$μg/24hrsである。AM100μg の場合は同様計算して

$1.7_7\times10^{-9}$ μg/24hrs でこの AM は 94% である故 $1.6_6\times10^{-9}$ μg/24hrs で 1/10 以下に低下している。従つてこの様にして *E. coli* の硝酸塩還元作用による亜硝酸塩生成量を定量して Aureomycin を定量出来る。

摘　　要

E. coli TYCC 9637の硝酸塩還元作用を利用して Aureomycin の定量を試み極めて簡単に定量出来た，その方法は

1）*E. coli* を硝酸塩を含む培地の懸濁液とし，これに既知濃度のAM溶液を加え37°C24時間培養後その生成亜硝酸塩を光電比色定量する。

2）この培地としては KNO_3・C_2H_5OH 培地が適当である。

3）*E. coli* 接種量は 10^5～10^9/ml なら亜硝酸塩定量時適当に希釈して定量出来る。

4）この培地を使つて37°C24時間培養後の亜硝酸塩生成量は接種菌量1個当り $1.8_5\times10^{-8}$ μg/24hrs でAM濃度100μgの場合は 1.6×10^{-9} μg/24hrsで1/10以下に低下している。

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放線菌の分離培養について※

中　野　道　紀

Studies on the Isolation of Antibacterial Streptmyces

By

Michinori NAKANO

Since Fleming (1929) described the *Penicillium notaum* as an effective inhibitor of *Staphylococcus*, and Waksman (1944) extracted streptmycin from *Streptmyces griseus*.

Many antimicrobial strains of *Streptmyces* have been isolated by a number of investigators in this field of science.

The author has made an attempt to isolate it from soil with a view to searching for antibacterial strain. The results obtained are as follow :

1. Indicated Czapek's agar is of little or no use to the isolation of *Streptmyces*. Casein agar is suitable for the isolation of *Streptmyces*.
2. When casein agar is acidified, fungi are found, but when alkalized, bacteria appear, and the suitable pH value is pH 6.8 for the isolation of *Streptmyces*.
3. Aureomycin is no good for the purpose, because, when soil is steeped in aureomycin solution before isolation, or supernatant fluid is added in media at the culturing time, fungi appear in media.
4. When suitable concentration of aureomycin is added to the shake culture of *Streptmyces*, the growth of it is promoted, but too strong a concentration inhibits the growth. The suitable concentration is about 5×10^{-5}, though it varies with its strain.

放線菌の溶菌性を示すことは Gasperini (1890) により報告され，その后 Rosenthal (1925), Gartia 及 Dath (1926) により研究されているが1929年 Fleming により *Penicillium notatum* の培養液の有効性を報告されてから[1] 放線菌も有用菌株として着目される様になり Waksman 等により1944年 *Streptmyces griseus* の代謝分泌物より Streptmycin が抽出されてから[2] 米国は勿論，わが国に於いても多くの研究者による報告は極めて多い。[3] [4] [5] [6] [7] 著者は抗菌性有効菌株の探索を目的とし，土壌よりその分離を試みた。

この研究にあたり御指導を仰いだ故小谷和夫教授に感謝する。

※ 水産講習所研究業績 第231号，1957年7月25日 受理

採 集 法

従来，放線菌は肥沃土壌に多いとされ，地表下10～20cmの所が分離培地に表れる糸状菌や細菌数が少く，放線菌が分離し易い[8]といわれ，地表下80cmではその65%が放線菌であると報告されている。著者は田畑・山林・荒地・洞穴内等の表地下10～20cmの所を掘つて，その10gを滅菌試験管に採取した。採集は北海道（阿寒・札幌・登別）宮城（松島）京都（天の橋立）鳥取（鳥取市）福岡（添田町）大分（別府市）宮崎（青島・高千穂）鹿児島（鹿児島市）佐賀（小城町）山口（下関市近傍）の各府県にわたつて行つた。

1 指示薬添加 Czapek's 寒天による分離

遠藤培地に赤変菌が表れるが，放線菌の探索に指示薬添加による着色培地を使用した方が，便利ではないかと思つて実験した。

実験方法及結果

採集した土壌を可及的迅速にその1gを9ml滅菌水に入れ，3分振盪した后，そのまま30分放置して，その上澄1mlを更に100倍に稀釈し，その1mlをペトリ皿に入れ，第1表に示す各種指示薬1～2滴を加え Czapek's 寒天又は普通寒天を注加して27°C 4～10日好気性及嫌気性培養し，次の結果を得た。

Table 1. Comparison of growth by the indicated Czapek's agar.

Cultured for 4 days at 27°C.

Indicator	Growth of colonies	Observation
Methylene blue	++ Blue or white colonies	Easy
Tashiro's reagent[9]	++	Easy
Neutral red	+	Uneasy
Methyl red	++	Easy
Bismark brown	++	Uneasy
Thymol blue	+	Easy
Brom phenol blue	++	Easy
Brom thymol blue	++	
Fuchusin	+	
Safrarine red	+ Pink colonies	Easy

菌株による指示薬の選択性は認められないが放線菌による M. B. の還元帯が認められ判別に便であつた。N. R. は Aspergillus による還元帯は認められたが，Mucor にては認められなかつた。この現象は Czapek's 寒天のみに表れ普通寒天には表れなかつた。田代試薬[9]は嫌気性培養に限り細菌による還元が認められた。

N.R. 及 Bismark brown は遊離色素の為，判別に不便を極めたが，他のものについては検鏡に際し，幾分便利であつた。

2 培 地 の 選 択

実験方法及結果

培地には Waksman's media, Vander Brook media 等があるが，中沢及藤井の報告(1953)[10]を参考に第2表に示す組成の培地に前記と同様稀釈した試料 1 ml を培養して放線菌の分離を試み比較した。

この6種の分離培地に現れた Colony を比較すると，その数は土壌を加えて蒸溜した蒸溜

Table 2. Composition of media for Isolation.

Each media was diluted by distilled water to 1000 ml finally and added 3.0 percent agar.

Czapek's agar		Casein agar		Starch agar		Glucose asparagine agar		Glucose agar	
K_2HPO_4	1	K_2HPO_4	0.5	K_2HPO_4	0.5	K_2HPO_4	0.5	Glueose	10
$MgSO_4 \cdot 7H_2O$	0.5	$MgSO_4 \cdot 7H_2O$	0.2	Starch	10	Asparagine	0.5	Meat ext.	3
Sugar	30	Glucose	1	NH_4Cl	0.5	Glueose	10	Peptone	5
$NaNO_3$	2	$Fe_2(SO_4)_3$	trace					NaCl	5
KCl	0.5	Casein	1						
$FeSO_4$	0.01								

Table 3. Appearance of streptmyces on the different media.

Media	Number of colonies		Number of streptmyces (%)
	Total	Streptmyces	Total No. of colonies
Czapek's agar	89	9	10
Czapek's (Soil distilled) *	108	13	12
Casein agar	75	28	38
Starch agar	60	12	20
Glucose Asparagine agar	35	5	13
Glucose agar	91	4	5

* Czapek's agar (soil distilled) : Composition was in table 2, diluted by the distilled water which distilled by the adding of soil.

水を用いた Czapek's 寒天が多いが，この Colony は細菌が多く，*Streptmyces* はその12%で Casein 寒天はその38%が *Streptmyces* で分離培地として最も優れていると思はれる。これは中沢及藤井の報告 (1953)[10] と一致している。

3 分離培地の pH の影響

分離培地の最適 pH をしらべるため，2% $CaCO_3$ にて中和した pH 6.0・6.4・6.6・6.8・7.0・7.2・7.6・8.0・8.4の Casein 寒天にて次の実験をした。

a) 土壌より分離する場合の影響

(1) 実験方法及結果

土壌1g を滅菌水にとりよく振盪した后，30分放置し，その上澄を100倍に稀釈して，その1mlを Casein 寒天に27°C 4日培養し，第4表の結果を得た。

(2) 実験方法及結果

土壌1g を滅菌水にとり上記と同様方法で27°C 4日培養して，その上に E. coli 10^4/ml を含むブイ一寒天を重層培養したが，良い結果は得られなかつた。尚 E. coli の噴霧培養も試みたが結果は思はしくなかつた。

b) *Streptmyces* を培養した場合の影響

(1) 実験方法及結果

著者が分離した *Streptmyces* C45 (仮番号) の胞子懸濁液を作り，その懸濁液 1ml を次表に示す各培地に培養し，第5表の結果を得た

Table 4. Comparison of appearance on the different pH casein agar.

Media (pH)		Mucor	Penicillium	Streptmyces		Bacteria	Total
				Appearance No.	Percent by total (%)		
Casein agar	6.0	41	1	21	33	0	63
	6.4	23	0	12	34	0	35
	6.6	31	0	16	34	0	47
	6.8	16	0	18	53	0	34
	7.0	18	0	11	38	0	29
	7.2	16	0	18 Colonies smaller than pH 6.8	50	2	36
	7.6	24 Growth scanty	0	13	33	2	39
	8.0	8	0	14	58	2	24
	8.4	11	0	16	55	1	28
Czapek's agar	7.0	52	3	1	2	6	62
Czapek's agar (soil distilled)	7.0	54	0	9	12	12	75
Glucose agar	7.0	22	0	0	—	5	27

Table 5. Comparison of appearance on the different pH casein agar in the case of pure culture on streptmyces.

Media (pH)		Number of colonies
Casein agar	6.0	1336
	6.4	1600
	6.6	1472
	6.8	1480
	7.0	1470
	7.2	1430
	7.6	1430
	8.0	1420
	8.4	1400
Czapek's agar	7.0	1120
Czapek's agar (soil distilled)	7.0	1948
Glucose agar	7.0	1544
Nutrient agar	7.0	1120

この結果から Casein 寒天の pH の変化による差はほとんど認め難い。尚 *Streptmyces* の純粋培養に於いて，この Colony 数から適否を判断するのは早計であるが，土壌を加えて蒸溜した蒸溜水にて調製した Czapek's 寒天に発育した Colony 数が他よりやや多く，発育が最も良好で純粋培養には最も適していると，思われる。

（2）実験方法及結果

Streptmyces C 45（仮番号）の抗菌性を利用して細菌の発育を阻止し，放線菌のみの発育を期待して，予め *Streptmyces* C 45（仮番号）を Casein 寒天に 27°C 4 日培養しておき，土壌 1 g を滅菌水にとり，100倍に稀釈して，滅菌濾紙にて濾過した后，その 3 白金耳を第 6 表に示す培地（45°Cに冷却）に入れ，これを予め *Streptmyces* C 45（仮番号）を培養した平板の上に重層培養し，第 6 表の結果を得た。

これらの実験で Casein 寒天はその pH が酸性に傾くとカビが発育し，アルカリ性に傾くと細菌の発育が見られ，pH 6.6～7.2ではその発育を見ず，pH 6.8及7.0は培地に表れた *Streptmyces* の発育が最も良好で，分離培地として，Casein 寒天を使用する場合 pH 6.8が最適と思われる。尚この実験で Casein 寒天が分離培地として優れていること及増菌を目的とした場合は土壌を蒸溜して作つた蒸溜水にて調製した Czapek's 寒天の方が優れていることを確認した。

Table 6. Comparison of appearance on the different pH casein agar cultured by double culture method.

Media	pH	Colonies No. streptmyces	Colonies of others
Casein agar	6.0	++	Fungi ++
	6.4	++	Fungi ++
	6.6	++	
	6.8	++	
	7.0	++	
	7.2	++ Colonies smaller than pH 6.8	
	7.6	++	Bacteria +−
	8.0	++	Bacteria +−
	8.4	++	Bacteria +−
Czapek's agar	7.0	++	Bacteria +−
Czapek's agar (soil distilled)	7.0	++	Fungi +−
Glucose agar	7.0	+	Bacteria ++
Nutrient agar	7.0	+−	Bacteria ++

4 Aureomycin (AM) の使用

AM溶液を分離培地に加えるか，培養前に土壌をAM溶液に浸漬することにより，細菌の発育を阻止し，放線菌の分離に便ではないかと思つてAM溶液を使つて放線菌の分離を試み，この結果思はしくなかつたので *Streptmyces* の発育に及す，AMの影響について実験した。

a) 分離培養えの使用

実験方法及結果

土壌1gを Bouillon に入れ，振盪して30分后その上澄 1 ml を 9 ml Bouillon に入れ，これに5×10^{-4} (g/ml) AM 1 ml を加え，よく振盪して90分放置して，その1 ml をブドー糖寒天を用いて培養時 5×10^{-4}(g/ml) AM 1 ml を加えて27°C 4 日培養し，次の結果を得た。

Table 7. Comparison of appearance on the media by the steeping in aureomycin solution.

Soil of	Steeped in AM 5×10^{-5} (90min)				Did not steep AM			
	AM added media		AM absence		AM adedd media		AM absence	
Cave	Fungi	2	Fungi Bacteria	7 5	Fungi Bacteria	5 2	Bacteria	2×10^3
Foot of mountain	Fungi	13	Fungi Bacteria	14 57	Fungi Bacteria	21 51	Fungi Bacteria	3 5×10^2
Cultivated ground	Fungi	30	Fungi Bacteria	36 15	Fungi Bacteria	43 33	Fungi Bacteria Streptmyces	6 5.4×10^2 5
Graveyard	Fungi	44	Fungi Bacteria	46 1	Fungi	46	Fungi Bacteria Streptmyces	6 2.1×10^2 8
Total	Fungi	89	Fungi Bacteria	103 78	Fungi Bacteria	115 86	Fungi Bacteria Streptmyces	12 2.2×10^3 13

第7表の如くAM溶液に浸漬するか，培地にAM溶液を加えたものは細菌の発育は抑制されてColony 数は少いがその反対にカビの発生が多い，このカビは発育は良好ではなく，AMはカビの生長促進因子として働くのではなく，細菌の発育が抑制された結果，カビの発芽が促進されたものと思はれる。

Streptmyces はAM溶液に浸漬した場合も，これを培地に加えた場合も発育して来なかつた。これはAM溶液が濃厚であつた為によるものか，尙他の培地についても実験しなければ不明であるが，*Streptmyces* の分離培養にAMを使用することは，カビの発芽を促進し不便であつた。

この結果を最初の細菌数とAM処理后の残存細菌数との比をもつて，その抵抗力を表し，その分離場所の湿度との関係を参考までに示すと次表の如く，他に比較し湿度10%以上高かつた洞穴内即高湿度で日光及風を受けない場所で分離した細菌はAMに対する抵抗力が最も弱い結果を示した。

Table 8. Survive percent of bacteria by the different part of humidity.

Part	Humidity (%) (Temp.)	Survive percent	
		AM 5×10^{-5} Steeped 90min	AM 5×10^{-5} Added media
Cave	69 (19°C)	0.16	0.07
Food of mountain	54 (21°C)	3.8	3.4
Cultivated ground	59 (22°C)	2.8	6.1

b) ***Streptmyces*** **の発育に及すAMの影響**

実験方法及結果

著者が分離した *Streptmyces* 101，102株（ともに仮番号）の胞子懸濁液（Bouillon pH 7.0)を作り，この1 mlをAM濃度0.2×10^{-5}，5×10^{-5}，8×10^{-5}，10^{-4}，2×10^{-4}(g/ml)のBouillonに接種して24°C 4日振盪培養してその結果を観察し次の結果を得た。

Table 9. Streptmyces growth change on the different aureomycin concentration of media by shake culture.

Shake cultured on 27°C 4 days.

Str.	AM concns. (g/ml)	Change of media	Diameter of growth (mm)
101	2×10^{-4}	Faint white brown	1
	1×10^{-4}	Faint white brown	1
	8×10^{-5}	Faint white brown	3
	5×10^{-5}	Faint white brown	10
	2×10^{-5}	Faint brown	12
	absence	Faint white brown	3
102	2×10^{-4}	Faint yellow brown	1
	1×10^{-4}	Faint yellow brown	12
	8×10^{-5}	Faint yellow brown	12
	5×10^{-5}	Faint brown	25
	2×10^{-5}	Faint brown	8
	absence	Faint brown	18

Streptmyces 101株（仮番号）はBouillon中に，マリモ様球状に発育した。その大きさはAM濃度5×10^{-5}及2×10^{-5}ではAMを加えないBouillon中に発育したものより，遙かに大きくAMによる

発育促進が見られる。*Streptmyces* 102株（仮番号）は綿様塊となり発育した。その大きさはAM濃度5×10^{-5}のみ，AMを加えない Bouillon に発育したものより大きく，その発育促進が見られるが，他の濃度のものはいづれもその発育の抑制が見られる。

これらから *Streptmyces* の振盪培養に際し，培地に適当濃度のAMを加えるとその発育促進作用があり，不適当濃度の場合はその発育を抑制される。その適当濃度は菌株による異るが 5×10^{-5} (g/ml) 位と判断される。

摘　　要

各地の地表下10～20cm の土壌から抗菌性有効放線菌株の探索を目的とし分離培養した結果

1）Czapek's 寒天に指示薬を加えて着色し，探索の便を計つたが大した効果はなかつた。

2）分離培地としては *Streptmyces* の発育率の高い Casein 寒天が適している。

3）Casein 寒天の pH が酸性に傾くとカビの発育を伴い分離には極めて不適当で，逆にアルカリ性に傾くと細菌の発育が多くなり，最適 pH は6.8である。

4）*Streptmyces* を予め27°C 4日培養し，その上に重層培養して，分離を試みた場合，結果は良好であつたが，先に土壌より分離培養したものに *E. coli* の重層培養を試みたものは，良い結果を得なかつた。

5）Aureomycin を分離培養時，培地に加えるか，分離前処理として Aureomycin 溶液に浸漬した場合，カビの発芽が促進され，Aureomycin を分離培養に使用することは不適当である。

6）*Streptmyces* を振盪培養する場合，培地に適当濃度の Aureomycin を加えると発育促進作用があり，不適当濃度の場合には抑制される。

この適当濃度は菌株により異るが5×10^{-5}位である。

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Press Ham の腐敗菌について※

中　野　道　紀

Some Experiments on the Putrefactive Bacteria of Press Ham

By

Michinori NAKANO

The results on the investigation of press ham are summarized as follows:

1. Main putrefactive bacteria of press ham are *Cl. sporogenes*, *B. megatherium* and *B. subtilis* etc.

2. These bacteria originally found in fish flesh still survive in spite of having been heated.

3. It takes 350 minutes and 8 minutes for some bacteria to be sterilized when they are heated in furacin solution (3×10^{-5} g/ml) and DHA solution (1×10^{-3} g/ml), at 80°C and at 100°C, respectively.

A社に於いて試作された Press Ham は僅々10日で腐敗した。この為その原料豚脂を 2×10^{-4} フラスキンで1分間洗滌する操作を加えたがこの場合でも保蔵期間を10日延長し得たに過ぎなかつた。この原因の究明を目的として次の実験を行つた。

この研究にあたり御指導を仰いだ故小谷和夫教授に感謝する。

実験試料：A社より提供を受けた Press Ham の正常品及腐敗品を使用した。この腐敗品はライフアン内にガスが発生していづれも稍々膨脹していた。又内部に水滴が附着して pH 5.4 程度で色，臭，味等も明らかに変化していた。これに対し正常品は pH 6.2程度で変化は見られなかつた。

これらの使用原料，混合割合及添加した防腐剤は次の様である。

カジキ固形3，鯨肉固形3，豚脂固形2，クロカワカジキ挽肉2，澱粉は全体の6%を使い，防腐剤としてデハイドロ酢酸（DHA）1×10^{-3} 及フラスキン 3×10^{-5}（n. f. として）を併用し，80°C 60分の殺菌加熱を行つたものである。

1　腐敗 Ham と正常 Ham の細菌について

実験方法及結果

腐敗品及正常品の1g 宛を夫々無菌的にとり，10ml の生理的食塩水に入れ，磨砕し充分振盪した後，この1ml を普通寒天にて嫌気性及好気性培養した。この結果は第1表及第2表の如くである。

※水産講習所研究業績 第232号，1957年7月25日 受理

Table 1. Bacteria number of press ham.

Each press ham wt. 1g.

Press ham \ Culture method	Aerobic	Anaerobic
Flat	3×10^2 *Bacillus* ++ *micrococcus* +	0
Swell	7.2×10^6 *Bacillus* ++	3×10^6

上表の如く正常品は好気性の桿菌及球菌 3×10^2 を含むのに対し腐敗品は菌数 7.2×10^6 でこの大半は嫌気性菌でこれらの好気性及嫌気性菌が Press Ham 腐敗の主働腐敗菌と思われる。

2　不良 Press Ham の組成別による腐敗菌の分離

Press Ham の腐敗は一見空中の雑菌が無秩序に関係すると思はれるが，加工処理に防腐剤を使用し，加熱殺菌するのでその腐敗菌は各原料により大体決ると考えられる。従つてそのいづれの部分が最も敗腐し易いか，不良 Press Ham の構成部分別に菌分離を試み，その分離菌について培養的性質をしらべた。

Table 2. Colonies form on agar source of flat press ham.

Colonies No.	Colour	Diameter (mm)	Shape	Elevation	Form	Number
1	white	10	circular	umbonate	short rods	50
2	white	5	circular	Flat	long rods	2
3	yellow	8	circular	Flat	chain rods	2
4	white	20	Irregular	Flat	rods	1

実験方法及結果

不良 Press Ham について製品の固形部分である鯨肉，魚肉，豚脂の部分及製品の表面，中心，鯨肉とその周囲との接触部分，豚脂とその周囲との接触部分，魚肉とその周囲との接触部分，表面下 1 cmの部分の 9 ケ所より夫々0.1gをとり 3×10^{-5} フラスキン・ブイヨン(pH 7.2) 10ml に入れ 37°C 24時間振盪培養した后，この液 1 ml を 100倍に稀釈して平板培養した。生じた Colony についてはその培養的性質をしらべた。結果は第 3 表及び第 4 表の如くである。

Table 3. Comparison of growth in the nutrient broth steeped each component of press ham swelled by the shake culture.

37°C 24hrs. shake cultured.

No.	Component and part	Clouding		Bacteria		Number of colonies
		1day	2days	Form	Motil	
1	Pig fat	--	+−	small rods	+−	a few
2	Whale meat	−	+−	large rods	+	many 0.01mm
3	Fish meat	−	+	large rods	−	many 0.5～1mm
4	Surface	+	++	short rods	++	many 0.5mm
5	Center	−	++	chain rods small rods	++ −	many 0.01mm
6	1cm from surface	−	+	long rods	++	many 0.01mm
7	Pig fat contact	−	−	chain rods	+	many 0.5～1mm
8	Whale meat contact	−	+−	many small rods a little rods	++ −	0.1mm 50 1mm 10
9	Fish meat contact	+−	++	large rods	+−	many 0.01mm

Table 4. Cultural characteristics of bacteria.
Source : Press ham swelled.

Strains	Agar stroke temperature 37°C, age 24hrs.					
	Growth	Form of growth	Lustre	Chromogenesis	Odor	Consistency
1	Moderate	Beaded	Glisting	—	Decided	Moist
2	Moderate	Echinulate	Dull	—	Decided	Butyrous
3	Moderate	Beaded	Glisting	—	Resembling	Moist
4	Moderate	Beaded	Glisting	—	Resembling	Moist
5	Scanty	Spreading	Glisting	—	Absent	Moist
6	Moderate	Spreading	Dull	—	Absent	Membranous
7	Moderate	Beaded	Glisting	—	Absent	Moist
8	Scanty	Spreading	Glisting	—	Absent	Moist
9	Moderate	Beaded	Glisting	—	Absent	Moist

		Nutrient broth temperature 37°C, age 24hrs.		
Medium	Condenced water	Surface growth	Clouding	Odor
Browned	Gray sediment +	None	Slight	Decided
Unchanged	Membranous surface sediment —	Membranous	Slight	Decided
Unchanged	Gray sediment +	None	Slight	Resembling
Browned	Gray sediment +	None	Moderate	Resembling
Unchanged	Gray sediment +	None	Moderate	Absent
Unchanged	Flocculent surface sediment —	Flocculent	Slight	Absent
Unchanged	Membranous surface sediment + —	Membranous	None	Absent
Unchanged	Sediment —	None	Slight	Absent
Unchanged	Membranous surface sediment —	Membranous	Moderate	Absent

	Peptone water temp. 37°C, age 24hrs.		Lactose nutrient broth			
Amount of sediment	Surface growth	Clouding	Amount of sediment	Surface growth	Clouding	Amount of sediment
Abundant	None	None	Scanty	None	None	Scanty
Scanty	Flocculent	None	Abundant	Flocculent	None	Scanty
Abundant	None	None	Scanty	None	None	Scanty
Abundant	None	None	Scanty	None	None	Scanty
Abundant	None	None	Scanty	None	None	Scanty
None	Flocculent	None	Scanty	Flocculent	None	Scanty
Abundant	Flocculent	None	Scanty	None	None	Scanty
None	None	None	None	None	None	Scanty
None	None	None	Scanty	Membranous	None	Scanty

Temp. 37°C, age 24hrs.		Litmus lactose nutrient broth temp. 37°C, age 24hrs.			
Das	Acid	Surface growth	Clouding	Amount of sediment	Acid
Not produced	Produced	None	None	Scanty	Produced
Not produced	Not produced	Flocculent	None	Scanty	Not produced
Not produced	Produced	None	None	Abundant	Produced
Not produced	Produced	None	None	Abundant	Produced
Not produced	Not produced	None	None	Scanty	Not produced
Not produced	Not produced	Flocculent	None	Scanty	Not produced
Not produced	Not produced	None	None	Abundant	Not produced
Not produced	Not produced	None	None	Scanty	Not produced
Not produced	Not produced	Membranous	None	Scanty	Not produced

Na-Citrate media temp. 37°C, age 24hrs.			Morphological		
			Vegetative cells		
Surface growth	Clouding	Amount of sediment	Form	Gram Stain	Flagella
None	None	Scanty	Rods	Positive	Peritrichic
None	Scanty	Scanty	Rods	Positive	Absent
None	None	Scanty	Rods	Positive	—
None	None	Scanty	Rods	Positive	Absent
None	None	Scanty	Rods	Negative	—
Flocculent	None	Scanty	Rods	Positive	Peritrichic
None	None	Scanty	Rods	Positive	Peritrichic
None	None	None	Rods	Negative	Peritrichic
None	Scanty	Scanty	Rods	Positive	Peritrichic

		Physiological		
Sporangia	Endospres	Methyl red reaction	Acetyl methyl carbinol	Indole
Drumsticks	Terminal	Positive	Negative	Negative
Elliptical	Subterminal	Negative	Negative	Negative
Spindled	Central	Positive	Negative	Negative
Elliptical	Central to subterminal	Positive	Negative	Negative
Elliptical	Terminal	Positive	Negative	Negative
Elliptical	Terminal to subterminal	Positive	Negative	Negative
Elliptical	Central	Negative	Positive	Negative
Elliptical	—	Positive	Negative	Negative
Elliptical	Central	Positive	Negative	Negative

これらの菌は Bergey's Manual of Determinative Bacteriology 6 ed. により検索し *Cl. Sprogenes*, *B. Megatherium*, *B. subtilis* 等と思われる。これらの菌は木俣等[4)6)]によりカマボコより，井野[3)]によりソーセージより分離されている。これらの嫌気性及好気性菌が Press Ham の主働腐敗菌と思われる。

3 耐熱性実験

実験2．によつて得た細菌の耐熱性を検討して Press Ham の殺菌温度及時間を見出す為次の実験を行つた。

実験方法及結果

前記9株の中，耐熱性予備実験に於いて耐熱性の最も強いと思われたNo. 9株について，その滅菌水懸濁液 1 ml を DHA 10^{-3}，DHA 10^{-3}＋フラスキン 3×10^{-5}，フラスキン 3×10^{-5} 濃度 (g/ml) のブイヨン (pH 7.0) 9 mlに入れ80°C，98°C，100°C で加熱后直ちに水冷してその 1 ml を平板培養し次の結果を得た。

最初の接種菌量によりその死滅所要時間は異る (坂口 1951)[1] 接種量 70/ml でこれを80°Cで加熱した場合，対照は70分を要した。これに対しフラスキンのもの及び DHA のものは50分で死滅し，これを併用したものは60分を要した。最初の菌量が 1.2×10^3/ml であつた場合，いづれの場合も 150分までは除々に減少したが対照はこれ以上長時間加熱してもその菌数は減少せず 150分 の加熱で生菌が除々に死滅し，残存した芽胞は80°C の加熱では死滅せず従つてこれ以上菌数は減少しないものと思われるが，加熱中の pH 等の測定を行つていないので尚検討の余地があるようである。

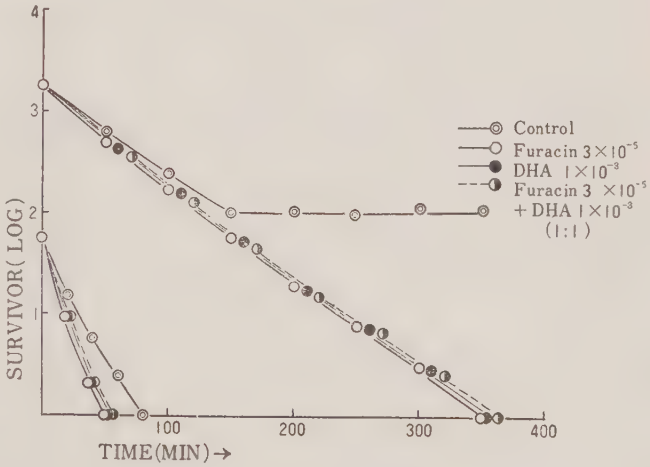

Fig. 1. Comparison of survivor after heating in the furacin solution and DHA solution in the case of different concentration of bacteria heated at 80°C.

最初の菌量が 1.2×10^3/ml で，これを 98°C にて殺菌加熱した時，対照は 14分フラスキン，DHA，両者併用のものはいづれも12分で死滅しこの場合は防腐剤による効果は顕著な差は認められない，これを100°C にて殺菌加熱した場合，対照は 9 分他はいづれも 8 分で防腐剤の効果は顕著でない。

これらの死滅曲線も一般の芽胞死滅曲線に一致する。

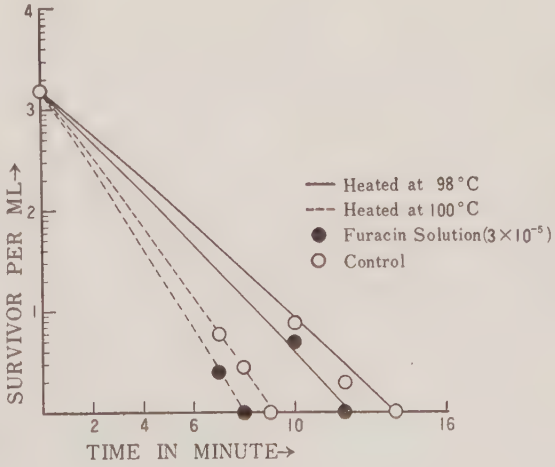

Fig. 2. Comparison of survivor heated in the furacin solution on the different temperature.

摘　　要

1）ライフアンケーシングした Press Ham よりその腐敗菌を分離した。

2）その主働腐敗菌は *Cl. sporogenes*, *B. subtilis*, *B. megatherium* 等の嫌気性菌及好気性菌と思われる。

3）これらの細菌は初め原料魚肉に含まれて加熱に耐えていたもので，その中の一株について耐熱実験した結果，菌濃度が1.2×10^{3}/ml でフラスキン3×10^{-5}又は DHA 10^{-3} の溶液中で加熱した場合，殺菌温度が80°Cの時は350分を要したが，100°Cでは僅か8分で死滅した。

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油脂鞣製法の検討※

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Considerations on Oil Tanning

By

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In this work we have considered oil tanning basing it on point of shrinkage temperature mainly treating shark skin. The results are as follows :

1) The shrinkage temperature of shark skin varies with its spieces, but in the same species. It does not vary, if the skin is processed by its drying, salting or pickling (Table 1.).

2) As for Tanning:

The skin is gradually tanned by simply dipping it in oil, for the shrinkage temperature of the dipped samples becomes higher gradually as the tanning time prolongs. (Table 2.)

Oil tanning heightens the shrinkage temperature of tanned one to 9—10°C higher than that of raw skin (Table 2,8.). The oil tanned samples, if processed preliminary with formaline, do not heighten, but hold or decrease the shrinkage temperature.

3) As for oils:

Shrinkage temp. of the samples tanned by sardine oil, skipper oil, whale oil and mekajiki (a kind of tuna) oil is higher in the order given above (Table 10.).

We have made an experiment on tanning by means of refined whale oil, hardened one, sulphonated one and one with its fatty acid, the sample tanned by refined oil is a little higher than the one by original oil, no change of the temperature by hardened oil, the one by sulphonated oil is a little lower, the one by original oil with fatty acid is much lower: and the one by fatty acid is the lowest. The same tendency is seen in the experiment by means of transformed skipper oils.

The samples tanned by blown skipper oil decrease the shrinkage temp. of its original skin (Table 10.).

Fatty acids are rappidly absorbed by the skin (Table 11.), but tanning

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with fatty acid from animal or vegetable oil decrease the shrinkage temperature of its original skin (Table 10).

4) As for tanning technique:

To apply fish oil directly to raw shark skin often makes the skin dry to stiff when the oiled skin is exposed to air. To raw skin, emulsified oil by water is good for tanninig (Table 5.). To salted skin many various kinds of oil can be easily used for tanning and preliminary drying of skin is unnecessary (Table 6.).

When oiled skin (tanned partially) is processed with formalin, its shrinkage temp. is 63°C, but when it contains much moisture it may shrink at 45°C (Table 7.). But dried oil skin endures 60°C in dry heat (Table 7.).

Heating dried oil skin does not heighten its shrinkage temp. of the tanned one (Table 8.) but wetting the skin heightens the temp (Table 7.).

The samples even if dried by the sun or by air, and exposed to ultra violet ray will have little or no effect on their shrinkage temperature.

本実験の分担は油脂関係は谷村，所要器具の作製及収縮温度の測定は上田，鞣作業は松沢が主として担当し全般の計画及其実施については三者の協議によつた。

緒　　言

皮革鞣製法には色々あるが油脂鞣は其工程及資材の両点に於いて，最簡易なものである。諸外国には相当利用されているが我国には一般化していないようである。我国の如く魚油を多産する所では特に活用すべき鞣法と考えられる。

油脂鞣の作業の一般方法は次のように要約される。「原料皮を予備処理して精皮とする。幾分乾燥した後適当の油脂で揉み油皮とする。これを展開し再び油揉みをする。展開油揉を4，5回繰返して得た油皮を加温して鞣化皮を得る。」[1] 又米国のオツトセイ毛皮の其も同じ趣旨のもので鞣製全工程（染色も含む）は90日を要す[2] と記されてある。

油脂鞣に関する諸説は次の通りである。

油脂の種類と用法……種類に就いては魚油及鯨油は共に確然と其使用効果が認められている。植物油に就いては「菜種油と綿実油とは良好であり，大豆油ヒマシ油桐油及アマニ油は不適当である。」[1] とするものと「植物油や陸棲動物油には真の鞣皮性がない。…卵黄油バター脳漿脊髄も鞣皮力を持つ。」[3] とするものとがある。

油質に就いては「沃度価の高いものを選ぶのであるが其他にも重要な性質がある。即ち可酸化性脂肪酸の含量の大きいものが強い鞣皮性を持つ。」[3] 又「沃度価が120乃至160の間にある油がシエーム革の鞣製に適し，120以下であると油鞣は緩漫に過ぎ160以上であると急速で強力に過ぎ共に不適当である。」[3]

油脂の使用法に就いては「単独に用いるよりは適当の乳化剤と混合した乳化油を用いることが皮に対する油の滲透な酸化分解等の作用を頗る迅速ならしめることが知られ，乳化油を用いることが多くなつた。」[1]

処理温度……皮質の鞣化には加温することが必要であると一般に認められている。「油鞣中の温度は20°Cを適当とする。…油揉皮は20°Cの屋内に3～4日晒し，次いで30～40°Cの加温

室にほぼ10時間吊し，最後に 50～55°C の室にほぼ3時間吊す°」[1] 又オツトセイ油脂鞣に於いては「各工程中皮は数回乾すか又は加温する。加温は周到の注意を以て 48.9°C 以上にならぬようにする。それ以上になると皮は悪変する°」[2] 以上の所見は実際上の結論と見られる。然し理論的実験に次のものがある。「皮粉を用いて結合油量を測定した成績は 30°C 30日間の処理ではタラ，アザラシ，サメ，イワシ，ニシン及びクヂラの各油では大差がないが 60°C 15日間の処理をするとイワシ油の結合油量が著増する。」[3]

鞣　化……是に就いては次の仮説がある。「油鞣に於いては皮質と不飽和酸基との間に化学変化を起し，生皮は耐久性の鞣皮となる。」[4] 又「魚油の如き高度不飽和脂肪酸を含む油が，油鞣に適当な理由は脂肪酸が先づ酸化して過酸化物を生ずる。…これがコラゲンと結合し…更にラクトン化する為に煮沸に対しても抵抗となるものと考えられる°」[5] 等の如く，皮質と結合するものは不飽和酸基，或は過酸化物とするものがある。別に「油鞣に於いては分子量の大きい fatty glyceride aldehyde や各種のアルデハイドの重合物が大きな力を持つ。」とする高分子化学的な推測も行われ初めている。

一般に「コラゲンヒ鞣剤との結合は先づ物理的に吸着し然る後化合するものと推定される。」[3] コラゲンの化学構造が決定されていない現在，その結合に就いて明確な説明を求めることは困難であろう。然し他の鞣製法，例へばクローム鞣に於いては塩基性クローム分子が高分子構造をとり，コロイド性が高くなるに従つて，其鞣皮力を増す事実が確認されているが，油脂鞣に於いては油脂の分解生産物がそのまま，或は重合して鞣化に参与すると推察されているに過ぎない。

検討の方法

この論文に於いては鞣製条件を変えて得た油脂鞣皮について，その熱収縮状況を観測して，その観測値を基準として鞣法を考究することとした。

鞣皮の収縮温度を以て考究の基準とした理由は次の二つにある。其一は鞣化度の検定にこの熱収縮が古くから慣用された為である。其二は近年に於けるコラゲンの化学研究に熱収縮がとりあげられ，その収縮機構が深く考察されて居り，且「魚皮の熱収縮は魚種別には差異がある。同種の場合は魚体の大小部位及切断の方向によつては差異がない°」[8] ことが明かにされている。又本実験に於いても其所説と同じ結果を示し又其値の精度が甚だよいことを確認出来た。斯様な実状は実験操作上甚だ都合のよい性格であり，又その値は信頼出来るものである。

鞣皮の熱収縮については此実験の進行中二種あることに気がついた。其一は熱収縮は同時に鞣皮としての性質を失う，例えば固化悪変して冷却後も復元しないようになるものである。其二は冷却後硬化等が消失し鞣皮としての諸性質を復元するものである。そして其一に属するものは収縮温度が原皮のそれより低下した場合に多く，其二は上昇したものに多い。従つて収縮温度は依然鞣化の重要な指針と考え得る。

鞣皮の性質として熱収縮以外の重要な実用的性質例えば柔軟性等に就いては適当な科学的表現法が見当らない為止むを得ぬ場合の外は省略することとした。

実　験

(1) 収縮温度の測定法

この測定装置は第1図の通りで，其原理は高橋氏[9] によつた。

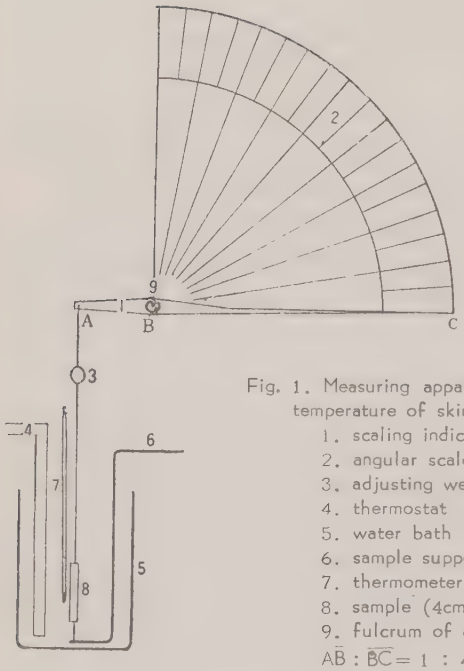

Fig. 1. Measuring apparatus for shrinkage temperature of skins.
1. scaling indicator
2. angular scale
3. adjusting weight
4. thermostat
5. water bath
6. sample supporter
7. thermometer
8. sample (4cm)
9. fulcrum of angular scale
$\overline{AB} : \overline{BC} = 1 : 4$ ($\overline{BC} = 20$cm)

測定する皮は湿潤状態にあらしめて後供用した。即ち原料皮及塩皮は水洗后，乾皮及鞣皮は5時間以上1夜流水中に浸漬して使用した。

所定の長さに切断した供試品を水中に容れ，その水を加温して温度を上昇せしめ，或は温度に達すると供試品は僅かに伸長する。次いで僅かな温度上昇と共に収縮を開始する。後の温度点を以て収縮温度とした。

（2）原皮の収縮湿度

この実験に使用した皮の種類クロサメ，アオサメ，ヤジフカ及牛皮床皮（ゼラチン原料用として輸入したもので軽く石灰処理し且乾固せるもの）の4つである。測定の結果これらの収縮温度は夫々48.0；51.0；55.5及53.5°C と見做される。そして

Table 1. Shrinkage temperature of skins.

No.	Shrimkage temp. (°C)	Skin
1	48.0	Kuro shark, raw
2	47.5	〃 , salted
3	52.0	〃 , shagreen dissolved off by HCl, tanned slightly with formaline
4	52.5	〃 , shagreen dissolved off by HCl, tanned slightly with formaline, and salted
5	69.8	〃 , shagreen dissolved off by HCl, tanned heavily with formaline
6	44.8	〃 , Thick skin adjacent dorsalfin shagreen dissolved off by HCl
7	50.5	Blue shark, Dorsal skin, raw
8	56.4	〃 , Thick tail skin, raw
9	51.0	〃 , Dorsal skin, raw　　Shagreen dissolved off by HCl
10	51.4	〃 , Belly skin, raw　　Shagreen dissolved off by HCl
11	63.0	〃 , Shagreen dissolved off by HCl, tanned heavily with formaline
12	54.0～57.0	Yaji shark, raw
13	54.0～56.5	〃 , dried
14	55.3	〃 , salted
15	55.0	〃 , grain side
16	54.8	〃 , meat side
17	53.0～54.0	Ox hide, meat side, slightly limed and dried

この数値は塩蔵，乾燥，或は塩酸脱鱗等の処理をうけても異動していない。然しフオルマリン処理は著しく異動せしめている。クロザメ皮に於いては約21°C アオサメ皮に於いては11°C 高

T. C …… thermal curve

S. C …… shrinkage curve

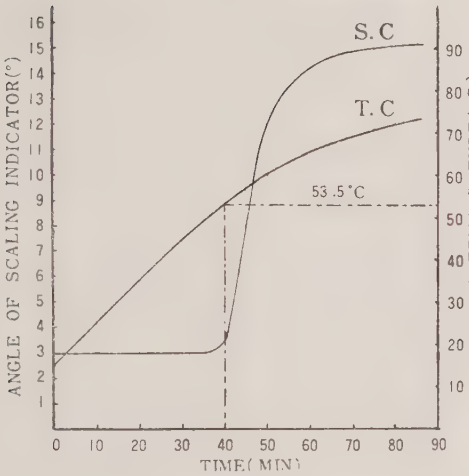

Fig. 2. Dry ox hide.

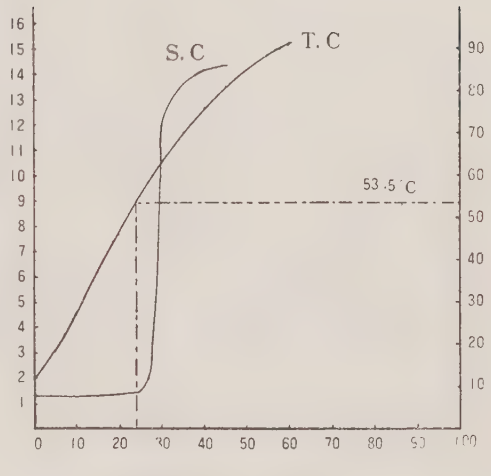

Fig. 3. Dry ox hide.

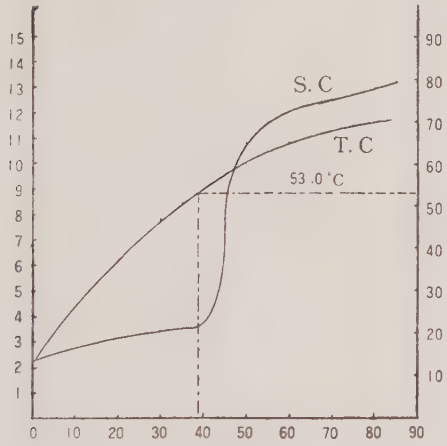

Fig. 4. Shark skin, raw.

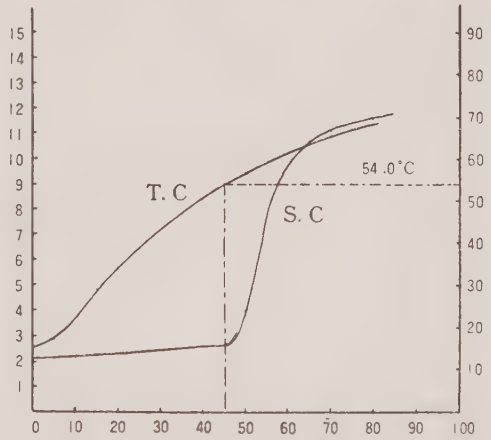

Fig. 5. Shark skin, dry.

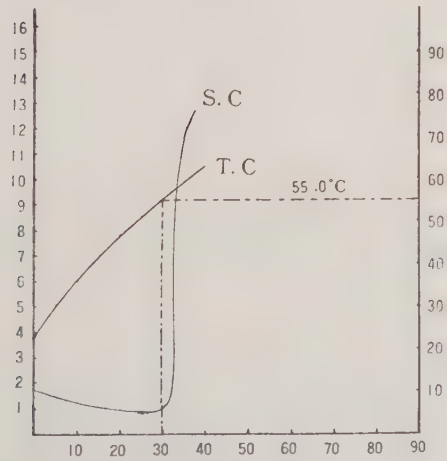

Fig. 6. Shark skin, salted.

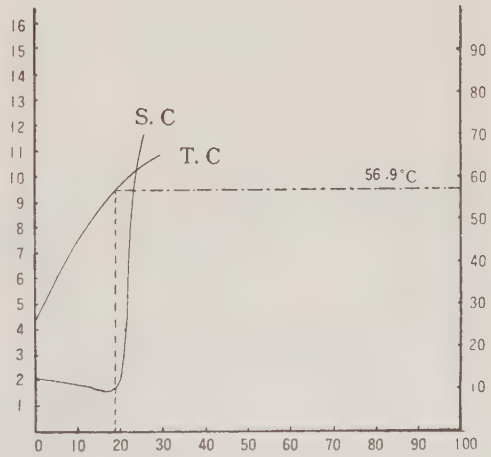

Fig. 7. Shark skin, tanned with refined whale oil.

めている。

皮の収縮温度は同種の場合其部位によつて差異のないことが明かにされて[8]いるが特種の部位即ち第1表 No. 6, No. 8 の如く甚だ肥厚した部位のものは相当の差異を示した。No. 6 の異常に低いのは厚さの関係で酸脱鱗后の中和が適当に行われなかつた為かも知れない。このもの及び No. 8 は特種構造の部位に当てをり，通常の皮と見做すことは妥当でないと思われる。兎に角此後の実験にはこの種の異常部位は供用しないこととした。

（3）油漬のみによる油脂鞣

油脂鞣の一般法は前記の如く精皮を油揉みし，これを展開即乾燥する作業を繰返すことである。この項の実験に於いては，展開作業の意義を知る為に，全くこの作業を行わず可検品を油脂中に浸漬するだけで鞣化が進行するか否かを調べてみた。

Table 2. Development of shrinkage temperature during the oil tanning.

Time \ No.	Shrinkage temperature 1	2	3
0	52.5～54.0	〃	〃
5 day	56.0	55.0	54.5
8	56.5	56.5	55.0
15	58.0	57.5	* 45.5
22	—	61.0	42.5
29	—	62.0	—
36	—	62.5	—
44	—	64.0	—
50	—	65.5	—
56	—	64.0	—
63	—	61.0	—
Tanning oil	Skipper oil	〃	Mackerel oil
Tanning method	Usual method	Dipped in oil, no drying	〃
Remarks	Samples are ox hide (meat side layer, not quain), slightly limed and dried to store. Dipped in running water, milled and squeezed moisture out by dry cloth and then tanned.		

* Sample is decayed.

この実験は二通りの成績を示し，其一は鯖油浸漬の場合である。即浸漬后10日頃より変質部が観察され日日その部の面積が拡大した15日目にはその部の中央は張力を失つていた。検言すれば油漬中に腐敗したのである。其二は No. 2 で供試皮の悪変は全く現われず，皮の色調の変化其他より鞣化が順調に進行しているものと観察され，又略1週間毎に其供試皮の一部を切取つて収縮温度を測定した。その成果は第2表の如く漸次上昇して50日目には 65.5°C を示した。然るに56日目には64.0 °C，63日目には 61.0°C と下降し，この測定で試料の全部を費消した為，その後の観測は出来なかつた。最後の供試皮片は収縮温度の測定後 94.2°C の熱水処理を行つてみたが，鞣皮の特質を具備して柔軟であつた。要するに其二は油中に浸漬するだけでも鞣化は進行することを示すものである。（経済的な鞣法であるか否かは別問題とする。）そして収縮温度の上昇が最高では10°C に近いことは注目に値しよう。

（4）原皮の急速脱水と油脂鞣

鮫皮は乾燥により固化し易い。特に気温の高い季節に迅速である。そして固化したものは水或は界面活性剤等によつても復元し難い。この現象は油鞣作業に於いて第1回の展開の際起り勝である。この悪変が起るとその后の工程が順調に進行しない。この予防法の一として無水硫酸ソーダ或酸性白土を生皮に添着もしめて更に槌で叩き皮内の水分の吸出しを強制して急速脱

水を行つた所大体20～30%，原皮重量を減少せしめ得た。斯く脱水した皮は固化し易いが固化せぬ中に油脂に接着せしめると，当初から吸油量が多くなり，鞣製中に固化の現象が全く見られなかつた。

Table 3. Dehydrating.

No.	Dehydrating			Shrinkage temp.
	Tanning period	Dehydrating	Oil	Skin	
4	May 7～16	Deprived moisture off by tapping the skin with anhydrous Na_2SO_4	Whale oil	Blue shark, raw	56.4
5	〃	〃 〃	〃	〃	56.5
6	May 10～15	〃 with Japanese clay	〃	Kuro shark, raw	47.3
7	〃	〃 〃	〃	〃	47.4
8	〃	〃 with anhydrous Na_2SO_4	〃	〃	52.3
9	〃	〃 〃	〃	〃	52.0
10	May 15～28	〃 〃	Sardine oil	Yaji shark, salted	55.0
11	〃	〃 〃	〃	〃	54.5
12	〃	〃 〃	〃	〃	54.8
13	〃	〃 〃	〃	〃	54.5
14	May 10～15	〃 〃	〃	Kuro shark, formaline tanned	62.0
15	〃	〃 〃	〃	〃	61.4

急速脱水皮を所定の油脂鞣処理をして得た鞣皮につき，収縮温度を測定した成績は第３表の通りである。

Table 4. Wetting in the progress of tanning.

Tanning process		Sample wt.		Tanning process		Sample wt.	
Process	Period	No.15	No.16	Process	Period	No.17	No.18
—	May 15	10.0	10.0	—	—	10.0	10.0
Drying	May 15—17	5.7	5.5	Drying	May 15～17	5.6	5.7
Oiling	May 17—20	9.0	9.4	Oiling	May 17～20	8.4	8.3
Drying	May 20 10h～15h	8.7	9.4	Drying	May 20, 10h～15h	8.0	8.0
Wetting	May 20, 15h～21, 10h	10.7	10.0	Wetting	May 20, 15h～21, 10h	9.9	9.9
Drying	—20, 10h～22, 10h	7.4	7.2	Drying	—21, 10h～26, 10h	7.4	7.6
Oiling	—22, 10h～23, 10h	9.2	9.0				
Drying	—23, 10h～26, 10h						
Shrinkage temp.		58.0	58.1			59.4	58.5

Tanning process		Sample wt.	
Process	Period	No.19	No.20
—	—	10.0	10.0
Drying	May 15～17	5.7	7.7
Oiling	May 17～20	8.6	8.3
Drying	May 20, 10h～26, 10h	8.7	8.0
Shrinkage temp.		56.5	56.4

Samples…Yaji shark skin, salted
Tanning oil…Sardine oil

アオザメ生皮の収縮温度は 51.0°C であるから No. 4．5 に於て約5°C上昇し，クロザメ生皮（No. 6，7）に於いては略同様で（No.8, 9）に於いては4°C 上昇し，ヤジ塩皮の場合は殆んど同様の値を示している。クロザメのホルマリン処理皮の場合は（No.14, 15）7～8°C 下降している。要するにこの急速脱水法は応用の可能性を認め得る。

（5）鞣化中の給湿

この実験にはヤジフカの塩皮を使用した。この目的は鮫皮の乾固を予防し得るか否かを知る為めである。又この実験全体の目的は鞣化工程中の給湿の影響を見ることにある。

実験成績は第4表の通りである。即鞣化工程中に給湿しなかつた No.19及 No.20の熱収縮温度は 56.4°C であり，これはヤジフカ塩皮の55.0に比し 約 1°C の上昇である。そして給湿を行つた No. 15, 16, 17, 18は58～59.4°C であり，3～4.4°C の上昇を示している。この事実から給湿は鞣化により影響を与えるものと考えられる。

（6）界面活性剤の利用

油脂鞣に界面活性剤を適用することの効果は既に認められている所である。その方法は魚油等を乳化剤を以て乳化するが，この実験では，その自身乳化性のある油脂を試用してみた。この成果は第5表の通り。

Table 5. Surfactants.

No.	Sample	Surfactant for tanning	Shrinkage temp.
21	Blue shark, raw	Lecithine＋water	53.5
22	〃	〃	53.7
23	〃	At beginning to 〔Lecithine＋water〕, thereafter to whale oil	53.1
24	〃	〃	53.5
25	〃	Whale oil emulsified with soapless soap	55.9
26	〃	〃	56.3
27	〃	Lecithine in petroleum	53.0
28	〃	〃	52.8
29	Blue shark, salted	Sulphonated whale oil	48.9
30	〃	〃	49.9
31	〃	Whale oil (control)	53.5
32	〃	〃	54.2
33	Kuro shark, formaline tanned	Lecithine ＋water	68.9
34	〃	〃	69.5
35	〃	Whale oil emulsified with soapless	67.0
36	〃	〃	69.8
37	〃	Lecithine in petroleum	65.7
38	〃	〃	65.6
39	〃	Sulphonated whale oil	66.5
40	〃	〃	68.2
41	〃	Whale oil (control)	66.4
42	〃	〃	65.0

試用した界面活性剤の鮫生皮及塩皮に対する効果はNo. 29, 30の硫酸化油鞣製品が原皮のそれより稍低い。その他の両検品は皆収縮温度を上昇させている。その中ソープレスソープ水液で乳化した鯨油が約6°C を高めて最高を示している。又硫酸化油（No. 29, 30）及レシチン石油液の両処理品（No .27, 28）は対称品の鯨油（No. 31, 32）より劣る。

ホルマリン処理皮に対する効果はソープレスソープ水乳化鯨油及水乳化レシチンが原皮とほぼ同じであり，他は皆収縮温度を下降せしめている。その中レシチン石油液が最低である。

レシチンの影響は生皮に対しては水乳化したもの（No. 21, 22）も石油液のもの（No. 27,

28)（後者が幾分低い傾がある。）も大体同じと見られる。然るにホルマリン処理皮に対しては水乳化物は約5°Cの差を以て石油液のものに勝つている。

硫酸化油は塩皮及ホルマリン処理の何れの皮に対してもNo. 40を除く外はよい効果を示していない。レシチンの用法や鯨油の乳化等の例から考えると，その本験実のように硫酸化油をそのまま使用したことが妥当でなく，加水乳化后使用したならば或は上記の成果と異たものが得られたかも知れない。

（7）原皮の乾燥

油揉工程に移る前皮を乾燥すると油脂の皮組織内への滲透が促進される。この事は当然油脂鞣に好影響を与えるであろうと考えて，この実験を行つたのであるが，この成果は第6表の如く約14%乾燥したものも，又24%乾燥したものも共に全く乾燥をしないものとその収縮温度に於いて差異が見られない。この成績は塩皮を使用したことが相当大きく影響したもので生皮を供用したならば或は乾燥の効果があらわれたかも知れない。

Table 6. Drying

Tanning process		Sample wt.		Tanning process		Sample wt.	
Process	Period	No.43	No.44	Process	Period	No.45	No.46
—	—	10.0	10.0	—	—	10.0	10.0
Drying	May 20, 11h～21,8h	7.8	7.5	Drying	May 20, 11h～15h	8.2	8.6
Oiling	21,8h～21,9h	10.2	10.0	Oiling	20, 15h～21,9h	10.5	10.8
Drying	21,9h～13h	8.9	10.1	Drying	21,9h～13h	10.3	10.7
Oiling	21, 13h～22,9h	11.7	12.3	Oiling	21, 13h～22,9h	11.7	12.3
Drying	22,9h～23,9h	10.7	11.5	Drying	22,9h～23,9h	10.8	11.3
Oiling	23,9h～24, 11h	12.6	13.6	Oiling	23.9h～24, 11h	12.7	13.0
Shrinkage temp.		56.0	56.5			56.5	57.4

（8）油脂鞣中の加温

鞣化中の油揉皮を加温することは禁じられている。[1)2)] 然しこれらは何れも生皮を原料とした場合である。ホルマリン処理皮のように耐熱性の高い場合はどうなるかを実験した。この成績は第7表の通りである。

Tanning process		Sample wt.	
Process	Period	No.47	No.48
—	—	10.0	10.0
Drying	…		
Oiling	May 20, 11h～21,9h	11.1	10.0
Drying	21,9h～13h	10.6	10.5
Oiling	21, 13h～22,9h	12.0	12.3
Drying	22,9h～23,9h	10.4	10.5
Oiling	23,9h～24, 11h	13.4	12.8
		56.7	56.4

Sample…Yaji shark skin. salted.
Oil…Sardine oil.

可検品の乾燥度は59～72%でこれに赤外線熱射を行つた。16分后の観察にNo.51, 52は形が大きく歪曲し，其中心が凝固していた。これを測温した所45°Cを示した。

照射を止めてその后は常法により鞣製して得た製品につき収縮温度を測定した。この数値を見ると対照区61.4～61.6に対し56.5～59.6であつて，乾燥度の高いものの収縮温度が高い。乾燥70%のものも熱凝固を起し，又起さなくても共にその収縮温度が低い。乾燥歩留が対称区より小でも収縮温度は低い。この事実は耐熱性の高いホルマリン処理皮の場合でも含水量の多い間

Table 7. Warming

No.	Sample wt. May 8	Sample wt. May 14	Exposed to ultra red ray	Shrinkage temp.	Remarks
49	10.0	5.9	16m	59.6	Tanning period…May 8～21
50	10.0	6.4	〃	59.0	Sample…Shark skin, tanned
51	10.0	7.0	〃 partially coaguleted at 45°C	56.5	heavily with formalin
52	10.0	7.0	〃 partially coagulated at 45°C	57.0	Tanning oil…Sardine oil
53	10.0	7.2	〃	57.5	
54	10.0	6.4	None (control)	61.4	
55	10.0	6.4	〃 (〃)	61.6	

に加温処理を行うことは甚だ危険である事を示すものであろう。

別の事項を考えてみる。もともとアオザメのホルマリン処理皮は 63.0°C で初めて熱収縮を起すものである。その油揉皮が此実験で僅か45°C で熱収縮を初めている。この事実は加温により，コラゲンを凝固せしめる物質の生成を想定しなければ理解出来ない所である。

Table 8. Heating

No.	Exposed to heat Date	Temp.	Time	Shrinkage temp.	
56	June 5	35～42	1h	57.0°C	
57	6	35～44	2		
	14	40～45	3		
	15	50	6	56.5	
	17	60	5		
58	June 5	35～42	2	56.5	
	13	40	6		
59	14	40	6		Shrinked during sundrying on June. 7 (46°C)
	15	50	6	56.5	
	17	60	5		
60	June 5	35～42	1		
	14	40～45	3	56.0	
61	15	50	6		
	17	60	2	56.5	
62	June 5	35～42	2		
	15	50	4	56.5	
63	〃	〃	〃	56.5	
64	Not heated (control)			57.5	
65	〃			55.5	

Manufacturing period…June 5～17
Sample…Kuro shark skin, salted
Tanning oil…Skipper oil
Heating…In drier with electric coil.

（9）油脂鞣中の加熱

この実験に於いて実験室のドライヤーを用い鞣製の初期には温度を低く鞣製の進むる従つて加温温度を高める方法によつた。ドライヤーが利用出来ない時は大気乾燥をした。（No. 59は 6 月 7 日の日干中に熱収縮を起した。）これらの成果は第 8 表の通り。

最高60°C 5時間の加熱処理を行つたのであるが全く熱処理をしないもの同じくその熱収縮温度は 56.5°C と見做される。換言すれば油揉皮を熱処理（乾熱）しても製品の熱収縮温度には影響がないことになる。

又 No. 59は45°C で熱収縮を起し 60°C 処理の 6 試料は皆熱収縮を起していない。これは試料の乾燥度によるものである。

ドライヤー中では 60°C に耐え，測定器中で約 56.5°C で収縮することは勿論乾熱と湿熱の差に基因するものであろう。この事例は多くの有機物に見られる所である。

クロザメ塩皮の熱収縮温度は47.5°Cである。この試製品のそれは56.5°Cである。鞣製によつて約9°Cの上昇を来したのである。この事は注目すべきであろう。

(10) 乾燥方法

天日乾燥と風乾と比較してみた。前者は，できるだけ直射日光に当て，後者は日光を全く避けて室内で乾燥した。前者の最高温度は42°C，後者は24°Cであつた。この結果は第9表の如く両者の収縮温度には殆んど差が見られない。

Table 9. Drying method

No.	Drying method	Shrinkage temp.(0°C)
66	Dried by sun	55.5
67	〃	57.0
68	Dried by air in the room	55.5
69	〃	55.0

Manufucturing period…May 21～June 1
Sample…Shark skin, salted
Tanning oil…Skipper oil

(11) 紫外線照射

この実験では試料を油揉毎に，その油皮に紫外線を照射し其影響を見た。この成果は第10表の通りである。即ち照射4日間（実時間32時間）に及んでも，その影響は現れていない。但，

Table 10. Ultra violet ray

No.	Time, exposed to the ray	Shrinkage	Remarks
70	4 days=32 h	Temp. 55.2	The sample is sxposed to the ray every every after the milling wth oil.
71	〃	55.4	〃
72	2 days=16 h	55.0	The sample is exposed to the ray after 1st and 2 nd milling.
73	〃	55.4	〃
74	None (control)	55.0	The sample is dried in the room avoid direct sun shine.
75	〃	55.6	〃

Manufacturing period…May 21～27 Sample…Yaji shark skin, salted. Tanning Oil…skipper oil

No.71の最終状態をみると，その発色は表裏の薄層にのみあつて内層に及んでいなかつた。この点から或は照射が不充分であつたか他に欠ける所があつた為に，この結果を致したのかも知れない。

(12) 油脂の種類

この実験では多くの動植物油を比較するというよりは同一種の油脂を形を変えてその影響を見ることを主とした。実験成績は第11表の通り。

油種別に収縮温度の最高をみるとイワシ油59.4，サンマ油57.0，鯨油56.9，メカヂキ油55.0であつた。大体沃度価順である。（この試料のヤジフカ塩皮のそれは55.3°Cである。）

脂肪酸鞣製品の収縮温度は皆低い。即ちサンマ油脂肪酸は 45.0～47.0°C，鯨油脂肪酸は42.0°C，植物油脂肪酸は42～43の範囲である。

加工油について見る。即ち鯨油関係では脱酸精製したものはせぬものより稍高い。精製しない鯨油にその脂肪酸を添加すると，その製品の収縮温度は低下する。脂肪酸のみで処理すると更に低下する。この現象はサンマ油の場合も全く同一である。この現象を第12表と対照すると

Table 11. Oils

No.	Manufacturing period	Oil for tan			Skin	Shrinkage temp. (°C)
		name	acid Value	Iodine value		
76	May 30～June 10	Whale oil	2.55	119.0	Yaji shark skin, salted	55.0
77	〃	〃	〃	〃	〃	56.0
78	June 3～17	Whale oil, refined	0.15	118.3	〃	56.5
79	〃	〃	〃	〃	〃	56.9
80		Whale oil, polymerized	3.53	91.8	〃	55.0
81		〃			〃	56.0
82		Whale oil, handened			〃	55.0
83		〃			〃	54.4
84	May 30～June 10	Fatty acid from whale oil	170.51	123.0	〃	42.0
85	〃	〃	〃	〃	〃	42.0
86		〔Whale oil〕+〔its Fatty acid〕	27.00	119.4	〃	54.7
87		〃	〃	〃	〃	54.0
88	June 5～17	Skipper oil	3.21	172.4	〃	56.5
89	〃	〃	〃	〃	〃	57.0
90	May 24～June 6	Sastane added to above	〃	〃	〃	53.0
91	〃				〃	54.0
92	May 30～June 10	Fatty acid from skipper oil.			〃	47.0
93	〃	〃			〃	45.0
94	June 3～17	〔Skipper oil〕	58.72	173.8	〃	51.0
95	〃	+ 〔its Fatty acid〕	〃	〃	〃	50.5
96	〃	Skipper oil, blown	3.26	163.9	Kuro shark skin, salted	51.5
97		〃	〃	〃	〃	53.4
98	May 20～26	Sardine oil	—	—	Yaji shark skin, salted	56.4～57.4
99	May 15～25	〃	—	—	〃	56.4～59.4
100	May 30～June 10	sword fish oil	5.18	121.9	〃	55.0
101	〃	〃	—	〃	〃	55.0
102	May 29～June 10	Oleic acid	—	—	〃	42.0
103	〃	〃	—	—	〃	41.3
104	〃	Fatty acid from rapeseed oil	—	—	〃	40.7
105	〃	〃	—	—	〃	40.7
106	〃	Fatty acid from castor oil	—	—	〃	43.0
107	〃	〃	—	—	〃	44.2
108	〃	Petroleum	—	—	〃	55.0
109	〃	〃	—	—	〃	55.0

興味が深い。同表によるとサンマ油を浅い容器に容れ空気に曝して放置すると元の酸化3.21が増加して4.58となつた。その同じ油を同じ状態に置き鞣製に使用した。それ故その油は少なくとも放置油と同じ位の酸価の増加はあるきべ筈であるのに，分析の結果は3.78であつた。サステンを加えて酸化を予防し乍ら鞣製に使用した油は酸価2.34を示した。斯様な鞣製中に脂肪酸が減少する事実は脂肪酸が選択的にコラゲンに吸着されたと考へるべきであろう。又前記の如く鯨油サンマ油に於いては酸価の少いものが，その鞣皮の収縮温度を高めている。その反対にサステンの如き抗酸化剤を混用して脂肪酸の生成を予防した油脂の鞣皮は収縮温度を低下して

いる。一見相反するようなこの二つの事実を解明することが油脂鞣製の本質の一部を解決することにならう。

又鯨油を 270～280°C で2時間重合した重合油及鯨硬化油は元の油と略同じ収縮温度を示し，その硫酸価油（Table 6）は低下している。

Table 12. Analysis for oil

	Treatment		
	Before	After	
Acid value	3.21	4.58	Setaside
Iodine value	172.4	164.8	
Acid value	3.21	3.78	Tanned No. 88,89
Iodine value	172.4	155.7	
Acid value	3.21	2.34	Mixed with sastane,(antioxydant)
Iodine value	172.4	170.4	Tanned No. 90,91

石油処理のそれは原皮と同じである。然し加熱 60°C 后その処理皮は熱凝固を起し変質したので鞣皮性は認められない。原皮の性質をそのまま保持したと考えるべきであろう。

要　　約

此実験に於いては鮫皮を主として，その油脂鞣製法を熱収縮温度の点から検討してみた。その成果を摘録すると次の通りである。

1）鮫皮も種類によつて熱収縮温度に差異がある。同種の場合部位により又は乾燥塩蔵及酸脱鱗等の処理によつて差異を生じない（表1）。

2）鞣化に就いては皮を油中に漬けたままでも鞣化は進行する。即ちその熱収縮温度は徐々であるが上昇する（表2）。

油脂鞣製による熱収縮温度の上昇はこの実験では最高9°C～10°Cであつた（表8，2）。

ホルマリン処理皮を油脂鞣製すると，その熱収縮温度を上昇せしめない。その温度を保持するか或は多くの場合低下せしめる（表5）。

3）鞣製用油脂についてはイワシ油，サンマ油鯨油及メタカヂキ油の別に見ると，その順で収縮温度が高い。

鯨油関係では，脱酸硬化，硫酸化及び特にその脂肪酸を加えたものを作製して検討した。元の油より脱酸精製油のものが稍高い。硫酸化油は低い。脂肪酸を加えたものは更に低く脂肪酸のみの場合はより低く最低を示した。脂肪酸の含有度の影響はサンマ油も全く同様である。

サンマ油に空気吸込（100～110°C 2時間）したものは収縮温度を低下せしめている（表10）。

脂肪酸は速に吸着されるが動物性植物性何れの油脂の場合も収縮温度が低下する　（表10，11）。

石油は鞣化に関係がなく，又皮の元の収縮温度をそのまま保持する（表10）。

4）鞣製作業については

生皮に魚油等を直接使用すると展開の時に乾固し易い。水性乳化油がよい（表5）。又生皮を脱水剤で急速脱水すると広い範囲の油脂を直接使用出来るが作業が面倒である（表3）。

塩皮にすると用油の範囲も広なり且予備乾燥の必要もない（表6）。

油採皮は含水量の多い場合その原皮の熱収縮温度が63°Cのものも45°Cで熱収縮を起すことがある（表7）。含水量の少い場合は 60°C 5時間の乾熱に耐え得る。然しこの熱処理によつて収縮温度は上昇していない。

油揉皮が或は乾燥度に達した時給湿すると収縮温度少しく上昇する。

日乾は温度過度に上昇することがありその為に皮質の熱凝固を含水量の多い時に起すことがあり，又風乾のみのものと熱収縮温度には差がない（表9）。

紫外線照射には大きな影響は見られない。

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罐詰の膨脹と罐の腐蝕について※

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Studies on the Swell and Internal Corrosion of Canned Foods

By

Yasumasa Ōba, Michinori Nakano, Tsuyoshi Yoshino
The late Keizaburo Miyauchi and Tomoyoshi Shiraishi

Electrolytic tin plates are widely used for canning in Japan. Various experiments have been made on the internal corrosion of canned fruits.

Canned "Mitsumame" swelled by chance, and these cans were made of the electrolytic tin plate and lacquered. We have studied on these swelled cans.

The results obtained are as follows.

1. It is difficult for microorganism to get isolated.
2. In manometric method, the active life which take up O_2 is recognized in the syrup of these swelled cans.
3. The active life is inhibited by aureomycin and chloramphenicol, but not inhibited by dihydrostreptomycin.
4. H_2 gas occupies above 70% of the total gas volume in these cans and Fe content in the can seems related with the can vacuum.
5. A large quantity of iron is contained in electrolytic tin plate cans.
6. Most of the iron content in the syrup is composed of Fe^{+2} and proportion between Fe^{+2} : Fe^{+3} is 62 : 16.

現在我国に於いても罐詰用空罐に電気鍍錫鉄力板が広く使用されるようになつたが，此の電気鍍錫罐の果実酸等に対する腐蝕試験は既に広く研究されている。Lueck and Brighton[1]は電気鍍錫鉄力罐は他の罐詰にはよいが，果実罐詰用としては期待に副い得なかつたと報告し，Davis[2]は電気鍍錫鉄力板から製作した塗料罐では使用に耐え得ると述べ，志賀[3]は電気鍍錫鉄力板を使用した内面塗料罐に於いては局部腐蝕は顕著に発展し，比較的早期に水素膨脹罐発生の原因をなすと報告している。このように一般には電気鍍錫鉄力は従来の熔融鉄力に比して著しく鍍錫量が少いので，これから製造した空罐は酸性度の高い内容物に対しては腐蝕し易いとされている。この欠点を補うために内面塗料罐が屢々使用されているのが現状である。

最近偶々電気鍍錫内面塗料罐を使用したA社製の"みつ豆罐詰"に膨脹罐が続出した，処が此のみつ豆罐詰は正常罐，膨脹罐共に巻締部に於いては差異は見られず，何れも良好であつた

※水産講習所研究業績 第234号，1957年7月25日 受理

が，膨脹罐は正常罐に比して罐内面腐蝕の程度が著しいように思われた。

其処でこれ等の罐詰の膨脹原因と内面腐蝕との関係を検討する目的で細菌学的研究，罐内瓦斯の定量並びに液汁中に溶存する鉄量の測定実験を行つた。

I　細菌学的研究

最初に細菌学的な面からこれらの罐詰の膨脹原因を見るために，微生物の分離培養及び Warburg manometer に依る検圧法を試みた。

実験試料

実験に使用したみつ豆罐詰は正常罐，膨脹罐共A社より提供を受けたもので1956年2月上旬に製造されたものである。

使用空罐は電気鍍錫鉄力を使用した5号罐で内面塗料を施したものであり，此の内面塗料は油性ワニス塗料の一種であるが，その製法についての詳細は明かでない。

初めにこれらの罐詰の中，膨脹罐10罐，正常罐5罐について液汁の pH 及び糖度を測定し併せて[illegible]的検査を行つた，これに使用した試料は微[illegible]，一部を[illegible]残余の内容物を当てた。この官能検査を綜合して見ると概して膨脹罐，正常罐共に巻締部には異常なく，罐内面には発銹もなく良好であつたが，内容物の状態には異状が認められた。即ち膨脹罐の内容物は微かに醱酵臭を帯び，味は適度の甘味があるが舌を刺す感があつた，又液汁は透明であつたが中には小気泡が見られ，内容物の中ミンゴ片は煮熟された状態で味もなく寒天の為め淡紅色に着色していた。

その他の内容物については膨脹罐，正常罐共に同様でミカンは萎縮し，寒天は青色，赤色のものは脆弱であつたが，無色の寒天は適度の強度があり，豆も適度の硬度があり変化は見られなかつた。

罐及び蓋底の内面には主として巻締部の円周一体と罐高に平行に走る線状の明かな罐材腐蝕が見られ，この外にも巻締部の周辺に点状の腐蝕が散在し，蓋底にも直線状の腐蝕が見られた，これらの腐蝕は正常罐，膨脹罐共に見られたが膨脹罐の方がその程度が顕著であつた。

Table 1. Comparison with pH and degree of sugar (Rf%) of canned mitsumame syrup.

Can No.	Date Manuf.	Date Test	pH	Degree of sugar (Rf%)	Cans vacuum (inch)
1	7. Fev. 1956	5. Nov. 1956	4.20		Swelled
2	〃	7. Nov.	4.27		〃
3	〃	8. Nov.	4.42	25.0	〃
4	〃	9. Nov.	4.48	25.3	〃
5	〃	14. Nov.	4.18	22.0	〃
Mean value			4.31	24.1	
6	9. Fev.	5. Nov.	3.96		Flat
7	〃	7. Nov.	4.10	23.5	〃 1.5
8	〃	8. Nov.	3.90	25.0	〃 7
9	〃	9. Nov.	4.08	24.5	〃 7
Mean value			4.01	24.3	

尚此等の罐詰の pH 及び糖度は第1表に示した。

表に明かなように膨脹罐液汁の pH 4.31であるのに対し，正常罐は4.01程度であつた，糖度は両者殆んど差は見られなかつた。

A　微生物の分離

実験方法

常法に依り開罐し，開罐直後内容物の微生物の分離を目的として培養し，其の残余の内容物については上述の様

に pH 及び糖度を測定し併せて官能検査を行つた。

分離培養は無菌室内で開罐直後その小孔より内容液汁 1 ml をとり，次に掲げた4種の培地 10ml を用い夫々1～10日又は1ヶ月間37°C で好気性培養及び嫌気性培養を行つた。

内容固形物については内容物（豆，寒天，リンゴ，ミカン）各1gをつぶして麹汁培地以外の培地を用いた。正常罐詰液汁を加えた普通寒天培地には培養時正常罐詰の液汁 5 ml と普通寒天 10ml を加えた。嫌気性培養は20%ピロガロール及び20%KOH を用いパラフィンで密封する方法によつた。麹汁培地によるものは24°C で1～10日間培養した。

培　　地

1）普通寒天（栄研）

2）正常罐詰液汁を加えた普通寒天

3）ブドー糖寒天

4）麹汁寒天

実 験 結 果

実験の結果は第2表に示した。

Table 2. Culture method and result.

Can No.	Date		Culture	Media					
	Manuf.	Test	Method	Syrup 5ml+Nutrient agar			Nutrient agar pH 7.0	Glucose agar pH 7.0	Koji agar
				pH 4.0	pH 6.0	pH 7.0			
1	7. Feb. 1956	5. Nov.	Areobic culture				0		0
2	〃	7	〃				0 *	0 *	0
3	〃	8	〃			0 *			
4	〃	9	〃	0	0	0			
5	〃	14	〃	0	0	0			
1	6. Feb.	5	Anaerobic culture					0	
2	〃	7	〃					0 *	
3	〃	8	〃			0			
4	〃	9	〃	0	0	0			
5	〃	14	〃	0	0	0			
Cultured at				37°C					24°C

0 —Absence of growth.

* —Cultured in can's matter.

表に見られる如く，その液汁及内容固形物から微生物の分離を目的とし，各種培地にて好気性及嫌気性培養を行つたが，いづれの場合も微生物の純粋分離は困難であつた。

B　検圧法による内容液汁の検査

実験A，に於いて微生物の純粋分離は困難を極めたので膨脹罐詰の液汁を Cell suspension として検圧法を試みた。

試　　薬

1）緩衝液

第3表に示す組成の Kreb's Ringer Phosphate (KRP) を CO_2 を含まぬ蒸溜水で

稀釈し，実験の都度新しく調整した，薬品は何れも和光純薬特級を使用した。

Table 3. Composition of Kreb's Ringer Phosphate (KRP).

Solution	%(w/v)	ml	Malarity
NaCl	0.90	100	1.5×10^{-1}
KCl	1.15	4	
$CaCl_2$	1.22	3	
KH_2PO_4	2.11	1	
$NaSO_4 7H_2O$	3.82	1	
M/15 Phosphate buffer pH4.0		19.56	

2）基　質

M/10 glucose：無水ブドー糖を使用直前 KRP にて調整した

3）懸濁液：稀釈を進行とするため，膨脹罐詰は 37°C に貯蔵し開罐直後に内容液汁をそのまま使用した。

4）阻害剤：

10^{-4} Chloramphenicol (CP)：三共薬品のものを10^{-4} (g/ml) とした。

10^{-4} Dihydrostreptmycine (DSM)：武田薬品のものを10^{-4} (g/ml) とした。

10^{-4} Aureomycin (AM)：武田薬品のものを10^{-4} (g/ml) とした。

これ等は精秤して調整した後直ちに冷蔵庫に貯蔵し古くならないものを使用した。

測 定 方 法

Warburg manometer（三田村製）を使用した。

Brodie's soln は Fuluorescin にて着色し，振盪数は 1 分間90，其の幅は 7 cmで温度は37.5 ±0.05°C に保つた。

反応全液を 2.00ml とし主室には基質 1.00ml 及び KRP 0.40ml を入れ，側室には 0.40ml の試料を入れた。阻害実験に於いてはCP 10^{-4}，DSM 10^{-4} 又は AM 10^{-4} の 0.20ml を主室に入れた。各測定は開始前15分間振盪し温度平衡を保ち，5分ごとに測定した。CO_2 は 15% KOH 0.4ml で吸収せしめた。

1）不良罐詰の液汁及び正常罐詰の液汁によるO_2吸収量の測定

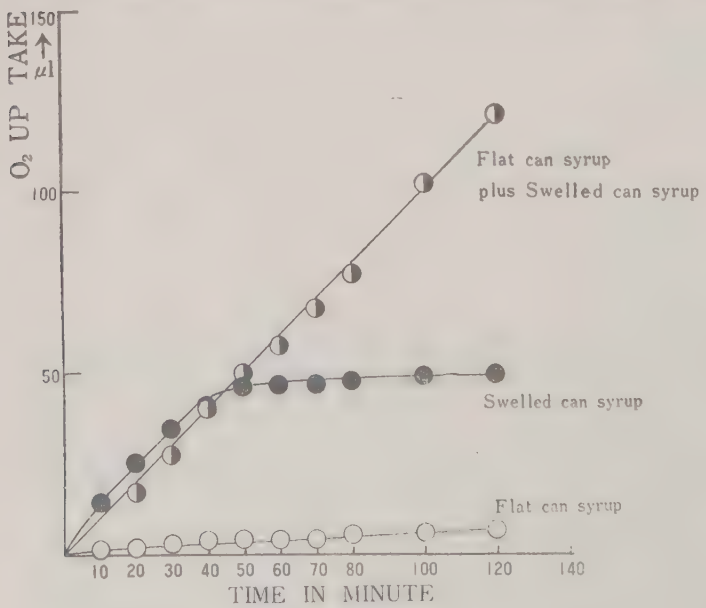

Fig. 1. O_2 up take of the canned mitsumame syrup.

(a) 正常罐詰液汁1.0ml，pH 4.30 の KRP 0.4ml と蒸溜水0.2ml を主室に入れ，正常罐詰液汁0.4ml を側室に入れた。

(b)（a）の正常罐詰液汁1.0ml の代りに膨脹罐詰液汁1.0ml を主室に，側室には膨脹罐詰液汁 0.4ml を入れた。

(c) 主室は（a）と同様，側室は（b）と同様にした。

実験の結果は第1図に示した。

この結果は正常罐詰の液汁 1.4ml を含む (a)

はO_2吸収は殆んどなく，active life は認められない，これに対し膨脹罐詰の液汁1.4 ml を含む（b）は最初O_2 吸収は大きいが40分を過ぎる頃から略水平となり O_2 吸収を示さず最早やこのactive lifeの基質としては利用されないことを示している，この両者を合せた（c）は時間と共に直線的にO_2 吸収は増加し正常罐詰の液汁は膨脹罐詰中の O_2 吸収の active life より基質として利用されることを示している。

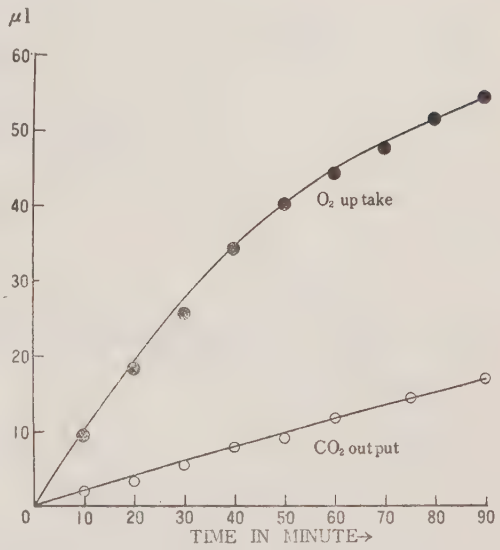

Fig. 2. Rate of change with O_2 up take and CO_2 out put by different pH of substrate.

2）基質のpHの影響

基質の pH の影響を見るため基質の pH を 4.0, 4.3, 5.0 の3種について M/10 glucose を基質としてその変化をしらべた結果第2図を得た。

基質の pH の変化による差は 4.0～5.0 の範囲に於いては O_2 吸収に影響は見られず，従つてこの範囲では pH はあまり重要 factor ではないと考えられる。

3）抗生物質による阻害実験

M/10 glucose 1.00ml, KRP 0.40ml及びCP, DSM, AM等の阻害剤溶液0.20ml を主室にとり，側室には膨脹罐詰液汁 0.40ml を入れて O_2 吸収量及び CO_2 放出量を測定した。

(a) CPによる阻害

CPによる阻害はCP濃度が10^{-4} 0.2ml を加えて全反応液の CP 濃度を10^{-5} とし，100分間測定し第3図の結果を得た。

O_2吸収はCPを加えたものは最初5分間CPの阻害によりO_2の吸収は殆んどないが，その後除々にO_2吸収を増加し30分後のO_2吸収阻害度は24%で60分後には29%，100分後には 35% と段々阻害度が上昇している。これに対しCO_2放出量は最初から60分頃まで殆んどその放出量が増加せず，30分後で

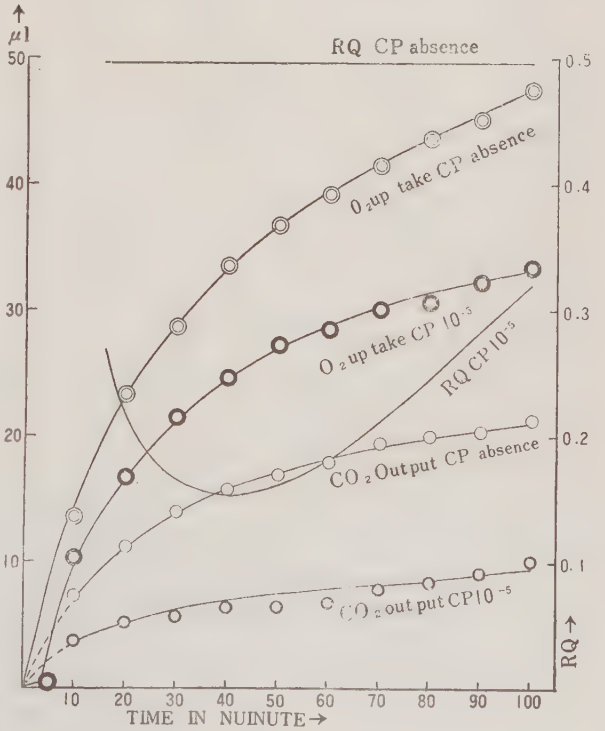

Fig. 3. Inhibitation of O_2 up take and CO_2 out put of canned mitsumame syrup by the chloramphemycol (10^{-5}).

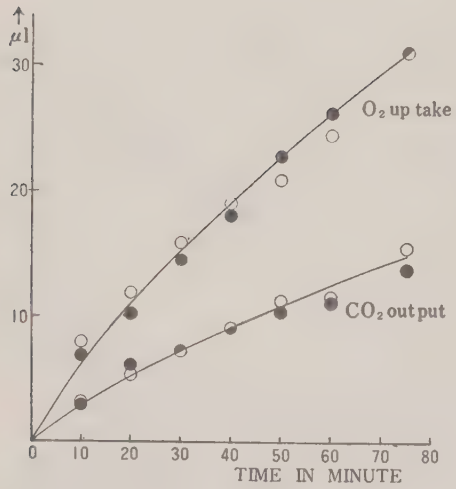

Fig. 4. Inhibitation of O_2 up take and CO_2 out put by the dihydrostreptmycin (10^{-5}).

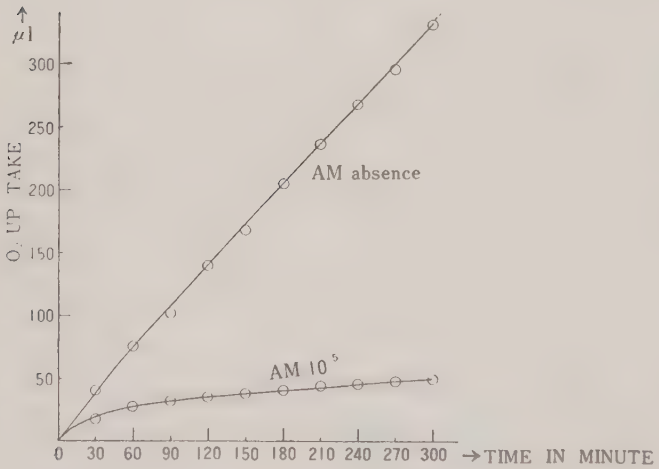

Fig. 5. Inhibitation of O_2 up take by the aureomycin.

はその阻害度は50%で60分後には63%に達し，100分後には52%になり，50%以上の阻害度を保つている，RQはCPを加えないものは0.5であるが，CPを加えたものは0.14まで低下し除々に増大し，100分後には0.3に達し除々に0.5に近づく。

(b) DSMによる阻害

DSM 10^{-4}溶液0.2mlを加え，DSM濃度10^{-5}として70分間測定した，その結果は第4図に掲げた。

(c) AMによる阻害

AM10^{-4}溶液0.2mlを加えAM濃度10^{-5}として300分間測定した，その結果は第5図に示した。

AMを加えないものは直線的にO_2吸収を増加し，AMを加えたものは15分頃から除々にO_2吸収は減少し，余りO_2吸収を示さない，阻害度を見ると15分後には44%，30分後には54%，1時間後には64%，2時間後には75%，3時間後には82%，4時間後には84%，5時間後には86%と除々にその阻害度を増している。

これらの一連の阻害実験により膨脹罐詰液汁中のO_2吸収作用を表わす active life はAMにより最も阻害され易く，次にCPにより阻害され，DSMでは阻害されないものと思われる。CPによる阻害実験ではCO_2吸収作用は除々に増加するのに対し，CO_2放出は急激に阻害され，そのまま平衡状態を保つことが観察される，又このRQの変化を見るとCPを加えないものは0.5近くであるが，CPを加えたものは始め小さいが，除々に増大し時間と共に0.5に漸近し，O_2吸収作用とCO_2放出作用とが夫々別個に阻害されているのではなく，液汁中に存在する微生物の生理作用が阻害されたものと考えられる。

II　罐内瓦斯について

罐詰の腐敗，膨脹の原因並びに罐内面腐蝕について検討する場合に，罐内瓦斯の検出，定量

は有力な手掛となるものである，従つて本実験に於いても膨脹罐詰及び正常罐詰について罐内瓦斯の分離定量を行い，併せて罐内面の腐蝕状態を調べた。

実 験 試 料

実験試料は，Ⅰと同じA社製の膨脹罐詰と正常罐詰を用いた。

実 験 試 薬

1) Potassium Hydroxide soln—CO_2吸収用
KOH 500gを水1 ℓに溶解す。

2) Alkaline Pyrogallol soln—O_2 吸収用
$C_6H_3(OH)_3$ 7 gを水25mlに溶解し KOH 50 g を水100ml に溶解せる液と混和調整す。

3) Ferrous Sulfate soln—NO 吸収用
$FeSO_4 \cdot 7H_2O$ 500 g を水1 ℓに溶解す。

4) Sodium Hydroxide soln—O_2電解発生用
NaOH 250 g を水1 ℓに溶解す。

実 験 方 法

Orsat 瓦斯分析装置の吸収管に夫々 Potassium Hydroxide soln, Alkaline Pyrogallol soln, Ferrous Sulphate soln を充鎮し，他の部分には水を充満し，瓦斯補集装置に連絡し，試料罐詰を水中にて開罐し，罐内瓦斯を Gas Burette 内に導入し，CO_2, O_2, NO の順に吸収定量を行い，残存瓦斯に一定量の O_2 瓦斯を混入，爆発 Pipette に移し，電池，感応コイルと連結して爆発燃焼を行い，瓦斯減量並びに CO_2 発生量から H_2 及び CO 瓦斯量を定量した。

実 験 結 果

実験結果は第4表に示した。

Table 4. Gas volumes (cc) in can.

Sample No.	Maker	Room temp. (°C)	Total weight of Can(g)	Total gas volume (cc)	CO_2 (cc)	O_2 (cc)	NO (cc)	CO (cc)	H_2 (cc)	H_2 (%)	Addition
10	A	21.5	273.0	44.5	1.0	0	0				Swelled can
11	A	17.1	273.5	42.5	0.5	0	0				〃
12	A	18.0	282.0	37.0	0.8	0	0				〃
13	A	19.0	243.0	40.0	0.8	0	0				〃
14	A	19.0	276.0	28.9	0.4	0	0	0			〃
15	A	16.0	276.0	48.8	0.9	0	0	0.2			〃
16	A	16.0	277.0	31.5	0.4	0	0	0.1			〃
17	A	16.0	277.0	27.0	0.7	0	0	0			〃
18	A	14.0	266.5	50.8	0.8	0	0	0.3	36.4	71.65	〃
19	A	14.0	276.0	38.8	0.6	0	0	0	28.2	72.72	〃
20	A	16.0	269.0	42.1	0.7	0.1	0	0.4	31.2	74.10	〃
21	A	17.0	292.0	13.6	0.4	0	0	0.1	8.0	58.82	〃
22	A	17.0	271.0	39.0	0.6	0.2	0	0	27.5	70.50	〃
23	A	14.0	277.0	19.2	0.7	0	0	0	8.5	44.26	Flat Can
24	A	13.0	278.0	16.9	0.5	0	0	0	7.3	43.19	〃
25	B	17.0	266.0	10.0	0.2	0	0	0	0.3	3.0	〃
26	B	17.0	266.0	11.5	0.3	0	0	0	5.1	44.34	〃

以上の実験結果から罐内瓦斯中には CO_2, O_2 等は僅かに存在するが，H_2 瓦斯が其の殆んどを占め，殊に正常罐詰と思われるものにあつては H_2 瓦斯量は44%程度に止まつているのに反し、膨脹罐詰に於いては罐内瓦斯中の70%以上を占めて居ることを知つた。これらの罐内面の腐蝕状況は巻締部の内面円周一体に腐蝕が見られ、更に此の円周に沿つて多数の点蝕が散在する。罐胴では罐筒に平行した直線状の腐蝕が数条又は数十条あり、罐蓋にも同様の線状腐蝕が見られた。

これらの腐蝕は機械的衝撃によつて内面塗料が剝離したか又は剝離し易い状態にあつたものが，果実酸等に依つて剝離し，露出面が腐蝕されたものと思われる。後掲写真（Plate 1）に見られる様に膨脹罐詰は正常罐詰に比して腐蝕の程度は著しい。

本実験に於いては実験の都合上真空度並びに pH を併せて測定出来なかつたので，H_2 瓦斯量と膨脹程度及び罐内面腐蝕の度合との関係を見ることは出来なかつたが，これについては後日検討する予定である。

III　液汁中に溶存する鉄について

実験II. に於いて膨脹罐詰にあつては罐内に多量の H_2 瓦斯の存在を見，又罐内面の罐材腐蝕が相当程度に進行していることが判つたので、その内容物と罐材に依り腐蝕の程度の差は当然考えられる。従つてこの様な腐蝕の結果，罐材の鉄は罐内に溶出すると考えられるので，次に罐内液汁中に溶存する鉄について検討を試みた。

実 験 試 料

実験試料 No.27～No.29 は実験 I, II. と同じものを用い，No.41～No.43 のミカン罐詰は本実験室で試作したものであり，他は市販のものを使用した。

実 験 試 薬

1）Fe standard soln

Ferrous ammonium sulfate $FeSO_4(NH_4)_2 \cdot SO_4 \cdot 6H_2O$ 再結晶し，其の0.2225+g を0.2%H_2SO_4 で溶解し，250ml とする。更に此の液を正確に10倍に稀釈す。0.01mg Fe/ml f=1.26785

2）Hydroquinon 1% soln

Hydroquinon $C_6H_6O_2$ (made in France, packed by K. M. R. Co.) 0.2g を Buffer soln pH=4.5, 20ml に溶解する。

3）Buffer soln, pH=4.5

2N Acetic acid CH_3COOH 14.3 ml に 2N Sodium acetate CH_3COONa 10.8ml を加え水にて 250ml とする。

4）O-Phenanthrolin 0.2% soln

O-Phenanthrolin $C_{12}H_8N_2$ 0.5g を conc HCl 5ml に溶解し，水にて200ml とする。

実 験 方 法

食品の鉄 (Fe) 含有量は特別に強化したもの以外は著しく少ないのが普通であり，従つて其の定量には殆んど例外なく比色法が用いられる。比色法には種々な方法があるが，O-Phenanthrolin 法を除いては発色の不安定，共存イオンの影響等の難点があるので，此処では同法を採用した。此の方法は現在広く普及されている方法であり，O-Phenanthrolin $C_{12}H_8N_2$ は一

定範囲の pH の下で $3C_{12}H_8N_2+Fe^{+2}\rightarrow (C_{12}H_8N_2)_3Fe^{+2}$ の如く第一鉄Fe^{+2}と反応して深紅色の錯塩を形成する，又第二鉄Fe^{+3}と反応して $3C_{12}H_8N_2+Fe^{+3}\rightarrow (C_{12}H_8N_2)_3\ Fe^{+3}$ となり淡黄緑色の錯塩を形成するが，第一鉄Fe^{+2} に比し，一層安定なる錯塩を形成するため，定量に際しては還元剤を用いて第二鉄Fe^{+3}を第一鉄Fe^{+2}となし，O-Phenanthrolin を加え，Sodium acetate CH_3COONa で pH を一定にし，発色した錯塩の紅色を比較して鉄の濃度を求めた。

試料みつ豆罐詰の液汁 5～10g を精秤し硫硝酸及び過塩素酸に依り湿式分解を行い，分解液を100mlに定容し，これより 1 ml を採取し，水を加えて 20ml とし，これの全量について次に記載する操作に従つて O-Phenanthrolin 法により比色定量を行つた。尙この定量を行うに先立つて，次の各項目についての予備的実験を行い，実験の条件を定めた，即ち Fe Standard soln 0.01mg Fe/mlを採取し，酸性溶液に Hydroquinon 1 % soln 1 ml を加えFe^{+3}をFe^{+2}に還元し，O-Phenanthrolin 2ml を加え，2 N CH_3COONa を滴下し pH を4.0に合せて水にて50mlとなし，この溶液を液槽 20mm の吸収セルに入れ，光電比色計（日立製 E.P.O—A 型）にて其の透過率を測定した。

1）光電比色計の疲労現象測定

光電比色計の疲労現象を測定するため，Sample 水，Filter BG 500mμ，Absorption cell 20mmに就いて実験を行つた。その結果点灯後2分を経過すれば常に同一光電流を起電することを知つた。

2）Filter の選定

C, BG, B, G, YB, O, R 等各種 Filter を使用して同様実験を行つた結果，吸光度の最も高い BG 500mμ を使用することとした。

3）発色の温度に依る影響

発色時の温度は 10～20°C が最適であることが判つた。

4）発色の pH に依る影響

pH2.40～6.00では発色に及ぼす影響はないことが判つた。

5）発色の時間に依る影響（発色の安定度）

Fe^{+2} と反応する O-Phenanthrolin の錯塩は発色直後より 72 時間は安定であることが判つた。

6）共存イオンの影響

同様実験に各種金属イオンを共存させ，操作を行い，透過率に及ぼす共存イオンの影響を調べた結果，Fe Standard soln 0.01mg Fe/ml，f=1.26785 中に Cu は10mg 共存すれば全然発色せず，淡青色をなして居り，1 mg以下では発色するが，多少妨害する，Co, Mn, As, Ni, Alは10mg 共存すれば妨害するが，1 mg 以下では全然妨害しない，又 Sn は 10mg 共存する時は白色の混濁を生じ，発色に影響するが，1 mg 以下では妨害しないことが判つた。

以上の様な条件を考慮に入れて本実験を行つた。

実 験 結 果

実験の結果は第5表に掲げた。表中 Sample No.40 まではみつ豆罐詰であるが，それ以下のものは参考のために行つた他の果実罐詰である。

罐内腐蝕度と鉄量との関係を見るため本実験を行つたものであるが，この実験の結果に依ると液汁 pH と溶存鉄量との関係は判然とは見られないが，一般に pH の高いものは鉄量は少

Table 5. Fe contents in syrup.

Sample No.	Maker	Can type (No.)	Variety	Vacuum (inch)	Fe γ/g syrup	Syrup pH	Addition
27	A	6	Mitsumame	(Swelled)	384.46	3.62	Electrolytic tin plates and lacquered can.
28	A	6	〃	0	154.49	3.92	〃
29	A	6	〃	0	141.01	3.92	〃
30	C	6	〃	5.3	33.90	4.15	Hot dipped tin plates can.
31	D	6	〃	2.0	40.74	4.32	〃
32	E	6	〃	3.0	31.68	3.92	〃
33	E	6	〃	3.0	32.19	3.92	〃
34	F	6	〃	3.0	31.79	3.45	〃
35	G	6	〃	5.8	5.95	4.80	〃
36	E	5	〃	11.0	15.28	3.60	〃
37	H	5	〃	15.0	11.57	3.90	〃
38	H	5	〃	11.4	4.93	4.05	〃
39	E	5	〃	10.9	17.00	3.85	〃
40	I	5	〃	2.0	1.22	3.60	〃
41	J	5	Mandarin Orange	10.2	8.90	3.30	〃
42	J	5	〃	9.0	3.66	3.40	〃
43	J	5	〃	8.0	2.57	3.40	〃
44	K	4	Water Melon	10.2	4.79	4.58	〃
45	L	3	Pine Apple	13.0	14.25	3.72	〃
46	M	4	Red Cherry	2.0	35.76	3.90	〃
47	M	4	Bartlett pear	12.5	25.70	3.85	〃
48	N	4	Fig	17.3	12.17	3.93	〃
49	O	4	Loquat	17.0	14.77	4.30	〃
50	P	5	Peach	14.0	17.04	4.92	〃

Table 6. Fe^{+2} contents in syrup.

Sample No.	Vacuum	Syrup pH	Total Fe (γ)	Fe^{+2} (γ)
27	(Swelled)	3.62	525.86	504.02
28	0	3.92	78.68	62.55

ない様である。

真空度と鉄量との間には鉄量が多い程真空度は低く，鉄量が少ない程真空度は高いことを示している。又電気鍍錫内面塗料罐では液汁 1 g 中に141 γ の Fe を溶存するに反し，熔融鍍錫無塗料罐では僅かにその 1/5～1/10を溶存するに過ぎなかつた。

第6表はFe^{+2}とFe^{+3}との溶存比を知るため液汁を硫硝酸及び過塩素酸で分解することなく測定を行つたもので，実験上の阻害因子はあるものと考えられるが，Fe^{+2}とFe^{+3}との大略の比率を知ることは出来るものと思われ，$Fe^{+3}/Fe^{+2}=16.13\gamma/62.55\gamma$ であつた。このことは罐内酸素の影響によるものと考えられる。

みつ豆罐詰の膨脹と罐内面腐蝕について行つた以上の実験結果を綜合検討して見るに，その微生物分離は困難であつたが，罐内瓦斯中に少量乍らCO_2が存在し，且つ Warburg manometer に依る検圧の結果は微生物が存在し，これ等の微生物はCP等に依つて阻害されることが

認められ，罐詰膨脹の一因をなすものと考えられるが，密閉罐詰内で，酸素不足の状態に於いても常時発育を進行して居るか否かに就いては本実験のみでは不明であり，今後研究の余地があると思われる。

罐詰内瓦斯の内，膨脹罐詰はその70%以上が H_2 瓦斯に依つて占められて居り，電気鍍錫内面塗料罐では液汁中の溶存鉄量が 14*r* 溶存するに反し，熔融鍍錫罐では僅かにその1/5～1/10に過ぎず，溶存鉄量と真空度との間には鉄量が多い程真空度が小さいことは，電気鍍錫罐は熔融鍍錫罐より鍍錫量が薄く，機械的衝撃やその他の原因で鉄面が露出し易く，そのため錫と鉄との間に電池を形成し，露出面の拡大が行われる結果鉄量が多くなると考えられる，此の場合内面塗料を施し完全に罐内が被覆されているならば特に電気鍍錫罐に於いて水素膨脹を起すということはないであろうが，本実験に見られる様に，この塗料が機械的衝撃等に依つて小部分と雖も剝離するか，剝離し易い状態となり，罐表面が露出した場合には著しい腐蝕を起す様である。

この溶存鉄量が直接罐の真空度に重大な関係を有し，引いては水素膨脹の主因をなすものと見られ，LUECK and BRIGHTON の実験結果と大体一致する。

要　　約

1．みつ豆罐詰の膨脹と罐内面腐蝕に就いて細菌学的研究，罐内瓦斯分析及び溶存鉄量の比色定量実験を行つた。

2．罐詰内細菌の分離は極めて困難で純粋分離するに至らなかつた。

3．検圧法によれば膨脹罐詰の液汁については O_2 吸収作用が認められ，active life の存在が考えられるが，正常罐詰の液汁については O_2 吸収は殆んど認められなかつた。

4．膨脹罐詰液汁中の O_2 吸収を示す active life はAM，CP により阻害されたが，DSM では阻害されなかつた。

5．膨脹罐詰内瓦斯はその70%以上が H_2 瓦斯に依つて占められていた。

6．電気鍍錫内面塗料罐詰の液汁中には多量の鉄を溶存し，殊に同種の膨脹罐詰にあつては著しく多量の鉄を溶存する，これに反し熔融鍍錫無塗料罐詰ではその溶存量は前者の1/5～1/10に過ぎなかつた。

7．液汁中に溶存する鉄量と罐内真空度との関係は鉄量が多くなる程真空度は低く，鉄量が少ない程真空度は高かつた。

8．液汁中に溶存する鉄は Fe^{+2} が大部分であつた。

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フラシンの防腐効果について※

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Studies on the Preservative Effect of Furacin

By

The late Kazuo KOTANI, Michinori NAKANO, Toshitsugu ŌTANI,
Akira ŌSHITA and Tatsuo MIURA

It has been known that the furan derivatives are effectual drugs for the preservative action of the development of microorganizms. The authors have investigated furacin for the purpose of studying the preservative effect of furacin solution on the putrefactive bacteria as follows:

1. Preservative effect of the furacin solntion on the putrefactive bacteria of fish.
2. Preservative effect of furacin solution on the aerobic sporeforming bacteria.
3. Effect of furacin solution on the sporegermination.
4. Effect of furacin solution on spores and vegetative cells on heating.

According to these experiments, the furacin solution is of little or no avail for either fresh fish or boiled ones, and is pretty available for the aerobic sporeforming bacteria, whose different effects are not recognized between the sporestaic condition and vegetative cell non-growth condition in the same concentration of vegetative cells and spores.

This solution has a little effect on spores and vegetative cells on heating, and the spores, when heated in this solution, become hard of germination.

フラシンの微生物発育抑制作用は，DODD 及 STILMAN (1944)[1] の研究により治療剤として，登場してより CAMMER 等 (1946)[2] の作用機作研究を始め，邦製フラシンについても多数の報告があり，[3][4][5] 食品に対しても有効な防腐剤であることが報告されている。[6][7][8]

著者等はこれが溶液として溶解している場合の魚肉腐敗菌に対する作用の研究を目的として次の実験をした。

本研究は故小谷和夫教授生前中，研究を共にしたものであるが，不幸にして逝去されたので，ここに纏めて報告する。

※ 水産講習所研究業績 第235号，1957年7月25日 受理

1　生鮮魚肉に附着する腐敗菌に対する効果

フラシンは魚肉鮮度保持に有効であることはすでに報告され（宇野）[7]、又他の防腐剤との効果も比較研究されているが（鉄本）[8]著者等は次の場合について実験した

a)　生鮮魚をそのまま浮游液とした場合

実験方法及結果

鮮度良好なサバを三枚におろし，骨皮，内臓を除き，磨砕後，可及的無菌的に裏濾した魚肉10gをフラシン濃度2×10^{-4}，1×10^{-4}，4×10^{-5}，2×10^{-5}，1×10^{-5}の各液100mlに浸漬して10% 魚肉浮游液として，27°C に貯蔵し，24時間ごとに普通寒天にて平板培養し，24時間後その Colony 数をしらべた。アジについても同様実験した。

実験結果は第1表に示した。

Table 1. Preservative effect of furacin on the fresh fish meat.
Cultured at 27°C mackerel meat.

Furacin concns. \ hrs.	0	24	48	72	PH
10^{-5}	2.5×10^{3}	1.2×10^{8}	1.0×10^{9}	5.2×10^{9}	6.8
2×10^{-5}	2.1×10^{3}	1.2×10^{8}	9.0×10^{8}	5.0×10^{9}	6.8
4×10^{-5}	2.0×10^{3}	9.0×10^{7}	1.6×10^{8}	2.7×10^{8}	6.8
10^{-4}	1.7×10^{3}	1.6×10^{7}	1.5×10^{8}	2.7×10^{8}	6.8
2×10^{-4}	1.7×10^{3}	1.0×10^{7}	1.0×10^{8}	1.9×10^{8}	6.8
Control	2.7×10^{3}	1.5×10^{8}	1.4×10^{9}	5.5×10^{9}	6.8

生鮮魚肉の保蔵を目的としてフラシン溶液を使用した場合，その濃度の増加と共にいくぶんその効果を増すが，その濃度2×10^{-5}以下では，殆んどその効果なく，4×10^{-5}以上で僅かに遅[illegible]を濃度で2×10^{-4}に於ても1～2日その延長を見るのみで，保蔵温度の低下を考慮せずして（宇野）[7]鮮度保持えの利用はあまり期待出来ぬ

b)　殺菌加熱した魚肉浮游液に海水を加えた場合

実験方法及結果

a）と同様処理したアジ魚肉を，フラシン各濃度の10% 浮游液とし100°C 20分加熱した後，海水1 ml を加え，これを前記と同様培養して，第2表の結果を得た

Table 2. Preservative effect of furacin on the sea water bacteria.
Bacteria content 2×10^{2}/ml in sea water.
Cultured at 27°C horse-mackerel.

Furacin concns. \ hrs.	0	24	48	72	96
10^{-5}	3	8×10^{2}	4.2×10^{4}	1.3×10^{8}	1.2×10^{9}
2×10^{-5}	2	6×10^{2}	2.2×10^{4}	6.3×10^{8}	2.0×10^{8}
4×10^{-5}	3	4.2×10^{2}	1.4×10^{4}	1.3×10^{7}	1.5×10^{8}
10^{-4}	2	0	0	0	0
2×10^{-4}	2	0	0	0	0
Control	3	3.5×10^{4}	8.5×10^{5}	4.0×10^{8}	1.7×10^{9}

[illegible]液中で加熱した魚肉浮游液に菌数2×10^{2}/mlの海水1 mlを加えた場合フラシン濃度4×10^{-5}以下では効果はあまり認められないが，10^{-4}以上では7日後に至るも発育を見ず，海水中の細菌は発育困難なものと思われる

c) 魚肉浮游液を殺菌加熱しこれに未加熱魚肉浮游液を加えた場合

実験方法及結果

b）と同様に処理した，サバ魚肉のフラシン各濃度の10%浮游液として，100°C 20分加熱した後，その未加熱魚肉浮游液1 ml を加え上記と同様 Colony 数をしらべ第3表を得た。

この場合ウロトロピンについても同様実験した。

一度フラシン溶液中で加熱した魚肉浮游液に加熱前の$\frac{1}{10}$量の腐敗菌を加えた場合，その防腐効果はあまり認められず，同様処理した。ウロトロピン溶液より僅かによい程度で対照と比べても2日位の延長が見られるのみである。この結果から一度フラシン溶液中で加熱した魚肉の保蔵に対しても腐敗源が他にある場合その保蔵効果はあまり期待出来ぬ。

Table 3. Preservative effect of furacin on the fish meat boiled.

Drugs concns. \ hrs.	0	24	48
Fracin 10^{-5}	2.6×10^{2}	2.0×10^{6}	5.0×10^{8}
2×10^{-5}	2.0×10^{2}	8.6×10^{5}	8.1×10^{7}
10^{-4}	1.8×10^{2}	2.1×10^{5}	7.8×10^{7}
2×10^{-4}	1.6×10^{2}	6.3×10^{4}	6.8×10^{7}
Urotoropin 10^{-5}	2.8×10^{2}	1.8×10^{6}	5.4×10^{8}
2×10^{-5}	2.0×10^{2}	1.7×10^{6}	5.0×10^{8}
10^{-4}	1.7×10^{2}	2.0×10^{5}	1.2×10^{8}
2×10^{-4}	1.5×10^{2}	2.0×10^{5}	$1.9\times10_{8}$
Control	3.6×10^{2}	2.5×10^{6}	5.9×10^{9}

b) 他の防腐剤との効果比較

ビタミンK_3の防腐効果は田中(1951)[12]山田(1952)[13]等により，亜硝酸塩については山田・矢野(1953)[14]の研究が夫々有効であることを報告している。著者等はフラシン・サルチドールB・$NaNO_2$・ビタミンK_3・ヒドロキシルアミンとその防腐効果を比較した。

実験方法及結果

各防腐剤溶液の濃度は2×10^{-4}（1：5000）10^{-4}（1：10000）5×10^{-5}（1：20000）とし，$NaNO_2$及ヒドロキシルアミンは直接水にとかし，フラシンは水にとかした後100°Cで10分沸騰した。サルチドールBは4 ml アルコールに0.02 g とかし加熱しつつ水を加えた。ビタミンK_3は0.02 g を2 ml のアルコールにとかし水を加えて生じた沈澱を加熱して溶解し，冷却後も沈澱が生じなくなつたものを用いた。

これらの溶液 10ml 中にイワシの骨皮，内臓を除き磨砕塊状として，その3 g を浸漬し直射日光をさけて室温 10°Cに放置し，24時間ごしにその 1 ml を平板培養してその菌数が10^{8}に達するまでの日数を比較した。

実験結果は第4表に示した。

生鮮魚肉の保蔵を対象として以上5種の防腐剤の効果を比較した場合，フラシン濃度5×10^{-5}のものは対照と同様3日後には腐敗し，その効果は認められないが，濃度の増加と共に保蔵日数も増し，2×10^{-4}では7日でこの様に保蔵温度を低下した場

Table 4. Comparison of the preservative effect with antibacterial drugs on the fresh fish meat Incubated at 10°C sardine fish.

Drugs \ Concns.	2×10^{-4}	10^{-4}	5×10^{-5}
Furacin	7	5	3
Salicidol B	7	6	4
$NaNO_3$	11	9	5
Vitamin K_3	7	7	4
Hydroxylamine	11	11	5
Control		3	

合，フラシンの効果を増している。これを他の防腐剤と比較すると

5×10^{-5}では，対照＝フラシン＜サルチドールB＝ビタミンK_3＜$NaNO_2$＝ヒドロキシルアミン

10^{-4}では，フラシン＜サルチドールB＜ビタミンK_3＜$NaNO_2$＜ヒドロキシルアミン

2×10^{-4}では，フラシン＜サルチドールB＝ビタミンK_3＜$NaNO_2$＝ヒドロキシルアミン

となりフラシンは生鮮魚肉の保蔵を目的とした場合優れた防腐剤とは云えない様である。

2　好気性芽胞菌に対する効果

フラシンは好気性芽胞菌には特異的に作用することは相磯等[6]により報告されているが著者等は魚肉より分離した耐熱性好気性芽胞菌に対する効果をしらべ，ウロトロピンとその効果を比較し，更にこれらを併用した場合の効果について実験した。

実　験　方　法

第5表に示すフラシンン及ウロトロピンの各濃度溶液の10%サバ魚肉浮游液 100ml を100°C 20分殺菌加熱し，予め魚肉より分離した耐熱性好気性等胞菌の芽胞の生理的食塩水懸濁液 1 ml を加え27°C に貯蔵し，24時間ごしに平仮培養しその菌数を比較した。結果は第5表に示した。

芽胞懸濁液：前記実験に於て比較的表れ易い発育良好の腐敗菌の芽胞懸濁液を80°C 20分加熱した後，生理的食塩水にて 4000rpm 15分遠沈洗滌した後，冷蔵庫に貯蔵した。

Table 5. Preservative effect of furacin and urotoropin on the aerobic spore forming bacteria

fresh mackerel fish meat suspension contained 2×10^5/ml of bacteria before heated, and spore suspension contained 1.1×10^2/ml. 0 hour zone of up number showed after heated and the others after spore suspension added.

Drugs \ Concns. \ Days		0	1	2	3	4	5	6	7
Furacin	1×10^{-5}	2.1×10 5.8×10	3.1×10^3	4×10^3	4.2×10^6	9×10^6	1.5×10^7	4×10^7	5×10^7
	2×10^{-5}	0 0	2.0×10^3	2×10^3	1.6×10^6	4×10^6	1×10^7	4×10^7	4×10^7
	1×10^{-4}	0 0	1.6×10^3	3×10^3	2×10^5	2×10^6	9×10^6	2.4×10^7	4×10^7
	2×10^{-4}	0 0	3×10^2	1×10^3	2×10^5	2×10^6	9×10^6	1.4×10^7	3×10^7
Urotoropin	1×10^{-5}	3.6×10 3.8×10	1×10^5	9.9×10^6	Putrefacted				
	2×10^{-5}	3.0×10 3.0×10	3.2×10^5	9.7×10^6	Putrefacted				
	1×10^{-4}	1×10 1.6×10	2×10^3	4×10^6	Putrefacted				
	2×10^{-4}	1×10 1.5×10	8×10^2	2.5×10^6	5.7×10^7	1.2×10^8	Putrefacted		
Furacin + Urotoropin (1 : 1)	1×10^{-4}	0 0	1×10^2	1×10^2	2.5×10^5	1.4×10^6	2×10^6	3×10^7	
Control		1.2×10^2 8.1×10^2	7×10^6	1.6×10^7	Putrefacted				

フラシンは好気性芽胞菌に対し，その濃度が稀薄な場合でも，相当の効果が見られる。

最初生鮮魚肉浮游液の菌数は 2.7×10^5 であつたものが 100°C20分加熱により，対照の場合 1.2×10^2 まで減少した。これに対しフラシン 1×10^{-5} のものは2.1×10となり，これ以上の濃度のものは，その発育を見ず，殺菌効果の増加が見られる。この加熱殺菌後に発育した菌は殺菌加熱後残存した芽胞と殺菌加熱後加えた芽胞との，両者の芽胞より発芽したものか，或はそのいづれか一方の芽胞の発芽による増殖を示すかは不明である。

ウロトロピンは対照に比し微かに効果を認められるが，その後の発育抑制作用はあまり認められない。即ちウロトロピンは加熱により防腐作用は失われ，2×10^{-4} で微かに防腐効果が見られるのみである。これをフラシンと併用した場合，フラシンを単独に使用した場合以上の効果は見られない。

3　芽胞の発芽に対する影響

Hachisuka 等 (1955)[15] は芽胞の発芽について Caramel の効果を報告しているが，著者等はフラシン溶液の芽胞の発芽に対する抑制作用と生菌の増殖に対する抑制作用の関係をしらべる目的で次の実験をした。

a)　生菌と芽胞とを夫々単独懸濁液とした場合

実　験　方　法

各濃度のフラシンを含む Bouillon (pH7.2) 9 mlに第6表に示す芽胞又は生菌の懸濁液1 mlを加えたもの2本宛を1組として32°Cに貯蔵し，24時間ごとに検鏡し発育を認めたものは平板培養した。結果は第7表に示した。

Table 6. Concentration of spores and vegetative cells for inoculation.

Rinsed several times in phosphate buffer solution by means of centrifuge and kept in ice chamber and filtered through paper pasteurized before experiment.

Strain no.	Spores	Vegetative cells	Source
1	2.4×10^8	2×10^8	Shrimp canned
2	2.1×10^8	2.7×10^8	Mackerel Fish
3	4×10^8	4.7×10^8	Sausage

Table 7. Inhibitation of sporegermination and vegetative cell growth in furacin solution inoculated with spore or vegetative cell alone.

Strain	Furacin concns. \ Days	1		2		3		4		5		6		7		8		9	
	Form of bacteria	V.C.	S.	V.C.	S.	V.C.	S.	V.C.	S.	V.C.	S.	V.C.	S.	V.C.	S.	V.C.	S.	V.C.	S.
1	1.56×10^{-5}	−	−	++	++														
	3.21×10^{-5}	−	−	++	−	++	++												
	6.25×10^{-5}	−	−	−	−	+	−	+	−	+	−	+	−	+	−	++	−	+	−
	1.25×10^{-4}	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	2.5×10^{-4}	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
2	1.56×10^{-5}	−	−	++	++														
	3.21×10^{-5}	−	−	++	++														
	6.25×10^{-5}	−	−	−	−	++	+	++	++										
	1.25×10^{-4}	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
	2.5×10^{-4}	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

	1.56×10^{-5}	− −	++ ++							
	3.21×10^{-5}	− −	++ ++							
3	6.25×10^{-5}	− −	− −	+ +	++ ++					
	1.25×10^{-4}	− −	− −	− −	− −	− −	− −	− −	+ +	+ +
	2.5×10^{-4}	− −	− −	− −	− −	− −	− −	− −	− −	− −

Showed V.C. : Vegetative cell　　S. : Spore　　++ : 2 test tube of growth
+ : One of them Growth　　− : Absence of growth

最初同濃度の生菌又は芽胞を夫々単独にフラシン溶液に加えた場合，生菌の増殖抑制作用も芽胞の発芽抑制作用もフラシン濃度の増加と共にその作用も強くなり，10^{-4} 以上ではかなり有効である。No.1株フラシン濃度6.25×10^{-5} に於ては3日目頃から除々に生菌は増殖しているが芽胞は9日に至るもその発育を見ないこれに対し，No. 2 株に於ては生菌の増殖と芽胞の発芽は殆んど差を認めず，No. 3 株に於ては全くこの差を認めない。これらから生菌の増殖抑制作用とその芽胞の発芽抑制作用とはほぼ同一と見られ，ある種の好気性芽胞菌については生菌の増殖可能なフラシン濃度に於ても芽胞の発芽は抑制されるものと思われる。

b)　生菌と芽胞が混在する場合

実験方法及結果

（1）　各種菌が附着していると思われる試料即ち，ポテート・イワシ・柿各0.5g，土壌・ワラ各3g，下水1mlをM/15燐酸塩緩衝液（pH7.2）10mlに入れ，滅菌濾紙にて濾過した後，その1mlを上記実験と同様 Bouillon 9mlに入れ，100°C20分加熱したものと，しないものを

Table 8. Inhibitation of sporegermination and vegetative cell growth in furacin solution inoculated with spores and vegetative cells together.

Source	Furacin concentration \ Days / Heating	1 H.	1 N.H.	2 H.	2 N.H.	3 H.	3 N.H.	4 H.	4 N.H.	5 H.	5 N.H.	6 H.	6 N.H.	7 H.	7 N.H.
Potato	5×10^{-5}	+	−	++	−	++	−	++	−	++	−	++	−	++	−
	1×10^{-4}	±	−	++	−	++	−	++	−	++	−	++	−	++	−
	2×10^{-4}	−	−	++	−	++	−	++	−	++	−	++	−	++	−
	Control	++	++												
Sewage	5×10^{-5}	−	−	++	−	++	−	++	−	++	−	++	−	++	−
	1×10^{-4}	−	−	++	−	++	−	++	−	++	−	++	−	++	−
	2×10^{-4}	−	−	++	−	++	−	++	−	++	−	++	−	++	−
	Control	++	+	++	+	++	++								
Sardine Fish	5×10^{-5}	++	−	++	−	++	−	++	−	++	−	++	−	++	−
	1×10^{-4}	+	−	++	−	++	−	++	−	++	−	++	−	++	−
	2×10^{-4}	−	−	++	−	++	−	++	−	++	−	++	−	++	−
	Control	+	−	++	++										
Persimmon	5×10^{-5}	++	++												
	1×10^{-4}	+	−	++	−	++	−	++	−	++	−	++	−	++	−
	2×10^{-5}	−	−	+	−	++	−	++	−	++	−	++	−	++	−
	Control	++	++												

Soil	5×10^{-5}	++	++										
	1×10^{-4}	++	−	++	++								
	2×10^{-4}	++	−	++	−	++	−	++	−	++	++		
	Control	++	++										
Rice straw	5×10^{-5}	++	−	++	−	++	−	++	−	++	−	++	−
	1×10^{-4}	++	−	++	−	++	−	++	−	++	−	++	−
	2×10^{-4}	++	−	++	−	++	−	++	−	++	−	++	−
	Control	++	++										

夫々2本宛，32°C に貯蔵して24時間ごとに検鏡して，発育を認めたものは平板培養した。結果は第8表に示した。

（2） エビの剝身10gをフラシン濃度1.25×10^{-4} 2.5×10^{-4} 3×10^{-1}の Bouillon 100ml に入れ100°C20分滅菌した後，32°Cに貯蔵して24時間ごとに，その1ml を平板培養した。結果は第1図に示した。

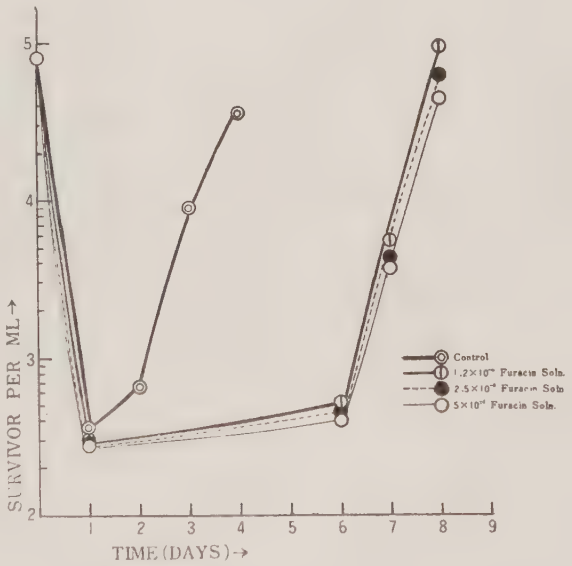

Fig. 1. Inhibitation of sporegermination in the furacin solution suspended shrimp meat in the case of Incuration after heating at 100°C

各試料について対照は殺菌加熱して32°Cに貯蔵した場合，1日後にはいづれも菌の発育を見るが，フラシン溶液中で加熱したものは，土壌より分離したものを除き，いづれも7日後に至るも発育を見ず，フラシン溶液中で殺菌加熱したものは，殺菌効果があがり菌が死滅したものか，或はこの溶液中で加熱したものは発芽が抑制されるかの場合及この双方の場合が考えられる。これをエビ剝身をフラシン溶液中で加熱したものを見ると，最初エビ生肉懸濁液には 8×10^4/ml の菌が存在したが100°C20分加熱した場合，対照は3.6×10^2まで減少し，フラシン溶液中で殺菌加熱したものは3.0×10^2，2.9×10^2，2.7×10^2とその濃度差に従つて微かに減少している，これらの菌数は対照に比し大差はなく，これを32°C に貯蔵した場合，対照は3日で菌の増殖を見るが，フラシン溶液中で殺菌加熱したものは7日後に菌の増殖を見，芽胞の発芽の抑制作用が見られる。

4 加熱殺菌時に於ける効果

Lewis等 (1954)[10]，Micher (1954)[16] はSubtilne の加熱殺菌時に於ける効果を，又清水等 (1954)[11] は電気殺菌時に於けるフラシンの熱効果につき報告している。著者等はフラシン溶液の加熱殺菌時に於ける効果をしらべる為次の場合について実験した。

a)　好気性芽胞菌に対する効果

実験方法及結果

土壌中より分離した好気性芽胞菌の芽胞のフラシン1×10⁻⁴の M/15燐酸塩緩衝液 1 ml 及フラシンを入れないもの 1 ml を夫々アンプル (0.5×3cmガラス管) に封じて冷蔵庫に貯蔵し，予め108°Cに加熱した食塩溶液中にアンプルを浸漬して加熱し，10分ごとに取り出して直ちに水冷し，その0.5ml を平板培養した。

結果は第2図に示した。

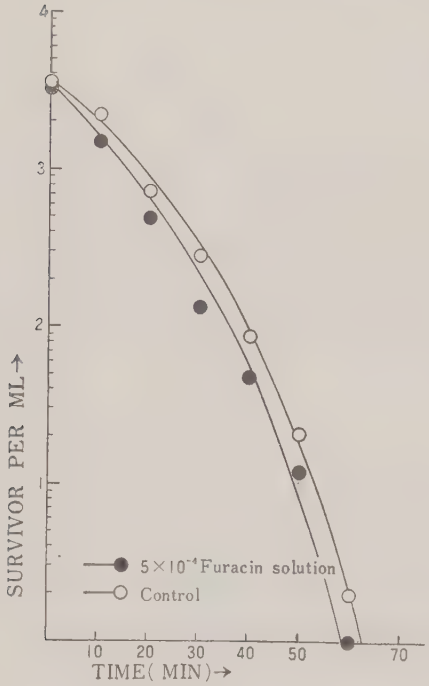

Fig. 2. Effect of furacin on the heating of spore at 108°C

b)　非芽胞形成菌の場合

実験方法及結果

フラシン濃度 5×10⁻⁴ の M/15 燐酸塩緩衝液 (pH7.2) の E. *coli* 懸濁液を 60°C にて加熱殺菌し，直ちに水冷した後，平板培養した。

実験結果は第3図に示した。

以上の結果から好気性芽胞菌の芽胞をフラシン溶液中で加熱した場合も，非芽胞菌を加熱した場合も対照に比し微かに殺菌加熱時に於ける殺菌効果の増加が認められるが，これを一定時間殺菌加熱した後の残存菌量には大差なく，この残存菌量差がその後の発育に影響を及し，その結果第1図に見られる様な対照との間に保蔵日数の差を生じるとは考えられぬ。従つてフラシン溶液中で加熱した芽胞は発芽し難い状態となり，その発芽が延長されるものと思われる。

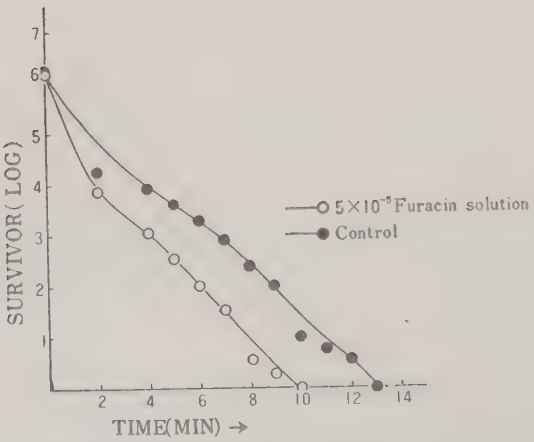

Fig. 3. E. coli survivor after heated at 60°C in the furacin solution (5×10⁻⁴)

摘　　要

1) フラシン溶液は生鮮魚肉の保蔵を目的とした場合その濃度の増加と共にいくぶんその効果を増すが 4×10⁻⁵ (g/ml n.f. として4×10⁻⁶)以下では，あまり効果なく，ビタミンK₃，$NaNO_2$，ヒドロキシルアミンに比し優れた効果は期待出来ぬ。

2) 一度フラシン溶液中で殺菌加熱したものも腐敗源が他にある場合あまり効果はない。

3) 好気性芽胞菌に対しては有効な防腐剤であり，一般にフラシン溶液の芽胞の発芽抑制効果もその生菌の発育抑制効

果も同程度と思われる。ある種の菌に対しては生菌の発育可能な濃度に於てもその芽胞の発芽の抑制作用が見られる。

4）フラシン溶液は加熱殺菌時殺菌効果はあがり，殺菌時間は短縮されるが，微かである。

5）フラシン溶液中で殺菌加熱した菌の発育が抑制されるのは，この溶液中で加熱した芽胞が発芽困難な状態となり，その発芽が延長される為と思われる。

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工場廃水に関する研究

第8報　石炭ガス工場廃水の処理に就いて※

赤　築　敬　一　郎

Studies on the Foul-water Drained from Factories.
8. Treatment of the Waste Liquor from Coal-gas Plants

By

Keiichiro Syazuki

The present paper deals with the removal of phenols contained in the waste liquor from coal-gas plants by the treatment with active carbon. The results obtained are as follows:

1. The volume of the waste liquor which can be treated with active carbon is affected by the concentration of phenols in the waste liquor, velocity of filtration of the waste liquor, size of active carbon, etc.
2. The proper velocity of filtration per ton of active carbon is found to be 20—30 m^3/hour.
3. The proper size of active carbon is found to be 0.5～1mm in diameter.
4. One ton of active carbon used in treatment can be recovered with 50 m^3 of benzene.
5. The absorptive power of recovered active carbon does not decrease with the increase of number of recovery.
6. The minimum quantity of active carbon for the treatment (X tons) can be calculated by the next formulas.

$$X=\frac{\frac{V}{B}}{M}\cdots\cdots(1)\qquad B=\frac{24}{T+t}\cdots\cdots(2)\qquad T=\frac{\frac{V}{B}}{S\cdot X}\cdots\cdots(3)$$

Note: V is the volume of the waste liquor (m^3/day). M is the volume of the waste liquor which can be treated with 1 ton of recovered active carbon (m^3). B is the maximum number of the treatment per day. T is the hour of one treatment. t is the hour of one recovery of active carbon. (about 2 hours). S is the velocity of filtration of waste liquor per ton of active carbon (m^3/hour).

※ 水産講習所研究業績 第236号，1957年7月25日 受理

緒　　言

石炭を乾溜してガスやコークスを製造する工場では石炭ガス水洗工程に於いて多量の石炭酸類を含んだ廃水が発生し，これを処理せずに河川，浅海等に排棄することは衛生及び水産上有害である。[1)~3)] この種廃水の処理に関しては蒸気蒸溜法，[4)] 溶媒抽出法，[5)~9)] 活性炭吸着法[10)~11)] 生物化学的方法等[12)~13)] 多数の業績が報告されているが，我国に於いては実際に処理を施している工場が少ない。この理由としては，従来の研究は欧米の大工場を対象としたものが多く，その結果をそのまま中小工場に適用するのが困難であり，又設備費に多額の費用を要する事等が考えられるので，著者は一般的に実用出来る簡易な方法及び様式を検討するため各種処理方法に関する基礎的実験を行つた。本文では活性炭により廃水中の石炭酸を吸着除去する方法についての実験結果を報告し，更に処理上の一般的様式に関して吟味した。

実 験 方 法 及 び 結 果

1. 試料，装置及び方法

供試液は石炭酸溶液及び東洋鋼鈑株式会社下松工場鉄板焼鈍用石炭ガス洗滌廃水（石炭酸含量420mg/L）を使用し，活性炭は和光製粒状炭を粉砕，篩合けしたものを実験に供した。

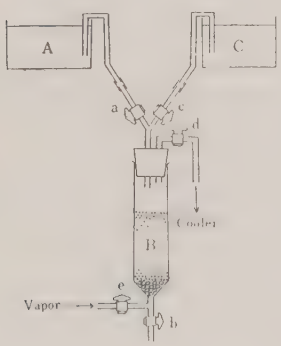

Fig. 1. Apparatus used in the experiment
A : Sample-reserver.
B : Adsorption-tower containing 10g. of active carbon.
C : Benzene-reservoir.
a,b,c,d,e : Stopcock.

実験装置は第1図に示す通りで，先ず試液溜槽Aより吸着塔B（活性炭10gを充填した内径 2cm の硝子管）に試液を滴下し炭層を濾過した処理液を200cc 毎に採取してその石炭酸濃度を定量し，活性炭粒の大きさ，濾過速度及び試液の石炭酸濃度の処理に及ぼす影響を検討した。次いでベンゼン溜槽CよりB（石炭酸を充分吸着させた活性炭を充填）にベンゼンを滴下し活性炭に吸着された石炭酸を抽出し炭層を濾過したベンゼンは 100cc 毎に採取してその石炭酸含量を測定し，抽出に要するベンゼン量を調べた。更にベンゼン洗滌を終えたBに活栓 e より蒸気を吹込み活性炭に吸着されたベンゼンをdを通じて除去した。最後に同じ活性炭に処理及び再生（ベンゼン抽出後蒸気洗滌）を交互に施し再生活性炭の石炭酸吸着力の変化を検討した。尚試液及びベンゼンの濾過速度は活栓 e で調節し，石炭酸の定量は前報[14)] の通りに行つた。

2. 試液の濾過速度

粒径 1～2mm の活性炭を充填した吸着塔に 500mg/L 石炭酸溶液を種々な速度で濾過させた場合の処理液の石炭酸濃度の変化は第2図に示す通りである。活性炭10g当りの処理可能液量（石炭酸が殆んど検出されない濾過液量）は濾過速度 100～150cc/時で 約 1.1L，200～300cc/時で 約 0.8L，500～600cc/時で 約 0.2L を示し濾過速度の早くなるにつれて少なくなり 1000cc/時 以上では処理目的を達することが出来ない。

3. 活性炭粒の大きさ

500mg/L 石炭酸溶液を 200～300cc/時 の速度で種々な大きさの活性炭を充填した吸着塔に濾過させた場合の処理液の石炭酸濃度の変化は第3図に示す通りである。処理可能液量は炭粒

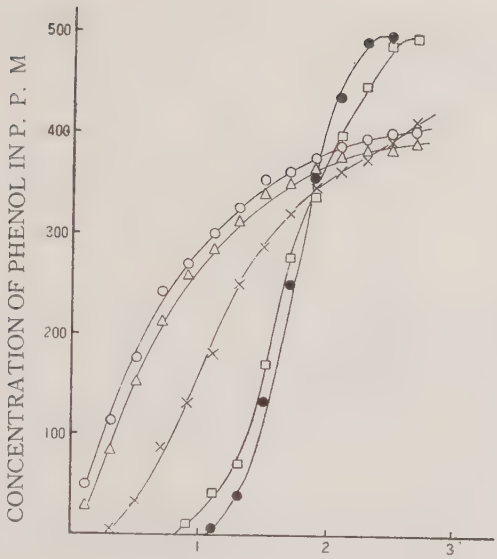

Fig. 2. Changes in the concentration of phenol in 500 p. p. m. phenol solution filtered through active carbon having 1—2mm in diameter at various velocity of filtration.
Velocities of filtration per 10g. of active carbon (cc/hour).
● 100～150　□ 200～300　× 500～600
△ 1000～1200　○ 1500～1700

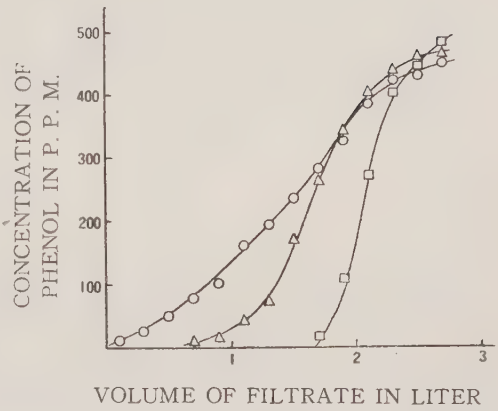

Fig. 3. Changes in the concentration of phenol in 500 p. p. m. phenol solution filtered through various size of active carbon at 200—300 cc/hour of velocity of filtration.
Diameters of active carbon.
□ 0.5～1mm　△ 1～2mm　○ 2～4mm

径 0.5～1 mm で約 1.6L，1～2 mm で約 0.8L，2～4 mm で約 0.1L を示し活性炭の小さいほど多くなる。

4. 試液の石炭酸濃度

500mg/L，750mg/L 及び 1000 mg/L 石炭酸溶液を粒径 0.5～1 mm の活性炭を充填した吸着塔に 200～300cc/時の速度で濾過させた場合の処理液の石炭酸濃度の変化は第4図に示す通りである。処理可能液量は試液の石炭酸濃度の高いほど少なく両者の間にほぼ反比例関係が認められる。

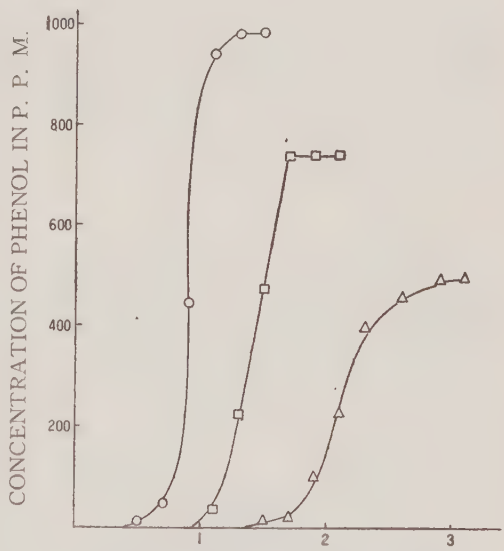

Fig. 4. Changes in concentration of phenol in various concentration of phenol solution filtered through active carbon having 0.5mm—1mm of diameter at 200—300 cc/hour of velocity of filtration.
Concentrations of phenol sample solution.
○ 500 p.p.m. ◐ 750 p.p.m. ◑ 1000 p.p.m.

5. 活性炭の再生に要するベンゼン量

500mg/L 石炭酸溶液を 3 L 濾過させた吸着塔にベンゼンを 1000cc/時の速度で滴下し，下端より流出するベンゼン中の石炭酸を定量した結果は第5図に示す通りである。活性炭に吸着された石炭酸は 500cc のベンゼンで約 80% が抽出，除去され，1000cc 以上のベンゼン中には殆んど石炭酸が検出されない。

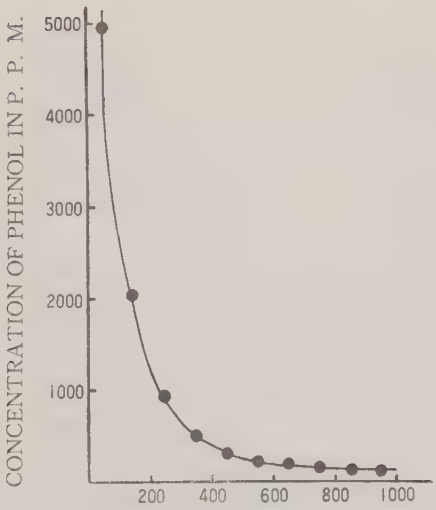

Fig. 5. Changes in concentration of phenol in benzene used for recovery of active carbon.

廃水で約 1.0L である。新しい活性炭の処理可能液量は石炭酸溶液と廃水とはほぼ等しく約 1.6L であるから再生活性炭の石炭酸吸着能力は石炭酸溶液で約81%，廃水で約 62.5% に低下する。

考　　察

本処理は実験結果より第7図のような系統図によつて実施することが出来るが，この場合に必要な資材としては活性炭，ベンゼン，苛性ソーダ及び蒸気が主なも

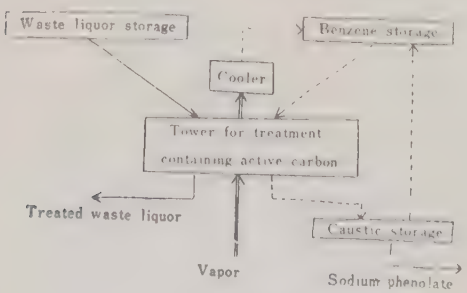

Fig. 7. Diagram showing treatment system.

—→ Waste liquor
----→ Benzene
⟹ Vapor

ベンゼン洗滌を終えた塔に蒸気を通じて洗滌した際に蒸気と共に溜出するベンゼンは5～6ccである。

6. 再生活性炭の吸着力能

0.5～1 mm 径活性炭を充塡した吸着塔に 500 mg/L 石炭酸溶液又は石炭ガス洗滌廃水を 200cc～300cc/時の速度で濾過させる処理操作とベンゼン 0.5L での抽出及び蒸気洗滌とによる活性炭再生操作を同一吸着塔に対して10回繰返し各回毎に処理液の石炭酸濃度の変化を調べた。新しい活性炭，第1回及び第10回目の再生活性炭の場合に於ける処理液の石炭酸濃度の変化は第6図に示す通りである。

再生活性炭の石炭酸吸着能力は再生回数に関係なく第1回と第10回目の間にも殆んど差が認められず，平均処理可能液量は石炭酸溶液で約1.3L，

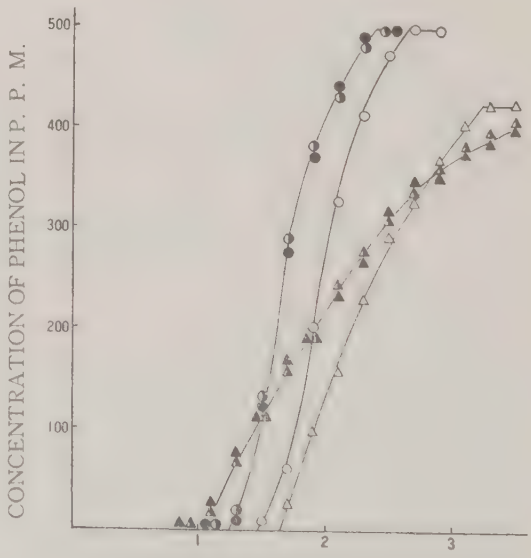

Fig. 6. Changes in concentration of phenol in 500 p. p. m. phenol solution and the waste liquor from coal-gas plants filtered through new and recovered active carbon.

Sample	Active carbon used
500 p. p. m. phenol solution	○ new
	◑ 1st recovered carbon
	● 10th recovered carbon
Waste liquor ……	△ new
	▲ 1st recovered carbon
	▲ 10th recovered carbon

のである。これらの中で特に活性炭は高価であるから品質及び価格を充分吟味する必要があり，又最小必要量を算定することは経済的に重要である。実験結果の示す如く活性炭の石炭酸吸着力には限度があり一定量の廃水を作用させるとそれ以後は急激に衰えるから一定時間毎に再生を施す必要がある。1日にB回ずつ処理及び再生操作を行う場合には活性炭の必要量（X屯）は次式によつて求めることが出来る。

$$X = \frac{\frac{V}{B}}{M} \quad \cdots\cdots\cdots(1)$$

上式に於いて，Vは廃水量（m^3/日），Mは活性炭1屯当りの処理可能液量（m^3）である。Mは活性炭の品質によつて異るのは勿論であるが，その他活性炭の大きさ，濾過速度，廃水の種類等の影響を受けるのは実験結果よりみて明らかである。活性炭粒は小さいほどMが多くなるが余り微小な場合は濾過速度が遅くなり大量の廃水を処理するのが困難であり，又廃水中の浮遊物が間隙を塞ぐ恐れがあるから粒径は最小 0.5～1 mm 程度が適当と考えられる。濾過速度は遅いほどMが多くなるから廃水量を考慮して活性炭1屯当り 30m^3/時以下になるように適当に調節する必要がある。再生活性炭の石炭酸吸着能力は新活性炭に比べてかなり低下し，その低下率は廃水の種類によつて差がある故，Mは処理を施こす廃水に対する再生活性炭の実測値を採用しなければならぬ。又同じ工場の廃水でも時間的な成分変化を示すから適当な期間中の平均成分濃度を測定しておく必要がある。以上の点に注意してMを実験により測定すると(1)式に於てVは既知数であるから活性炭の必要量Xは処理回数Bに反比例することになる。

処理回数は作業上適当に定めてもよいが活性炭は高価であるから経済的には処理回数を出来る限り多くして活性炭の必要量を少なくする方が有利である。1日間に可能な最大処理回数Bは1回の処理に要する時間をT時間，活性炭の再生に要する時間をt時間とすれば次式から求められる。

$$B = \frac{24}{T + t} \quad \cdots\cdots\cdots(2)$$

活性炭の再生に要する時間はベンセン抽出に約0.5時間，蒸気洗滌に約0.5時間及びその他の雑作業に0.5～1時間，合計して約2時間あればよい，即ちt＝2と置いてよい。又処理時間は濾過速度S（m^3/屯・時）に反比例し，1回に処理する廃水量 V/B（m^3）に比例するから次の関係が成立する。

$$T = \frac{\frac{V}{B}}{S \cdot X} \quad \cdots\cdots\cdots(3)$$

上記した(1)，(2)，(3)式よりV，M及びSを既知数として実際の処理上に必要なX，B及びTを算定することが出来る。本実験に使用した活性炭（粒径 0.5～1 mm）の供試廃水に対するMはS＝25（m^3/屯・時）に於いて約100m^3であるから，Vを500m^3/日とすればX＝1.25屯，B＝4回，T＝4時間となる。

次に活性炭の再生には50m^3/屯のベンゼンを必要とするが，実際にはベンゼンは循環，精製して繰返し使用出来るし，又蒸気洗滌の際に溜出するベンゼンは0.5～0.6m^3/屯であるが，これも回収して再使用出来るから損耗するベンゼンは極く少量と考えられる。尚ベンゼンによつて抽出された石炭酸類の回収に関しては種々の方法があるが，本処理を実施するに当つてはこれに就いても検討する必要がある。

摘　　要

1．石炭ガス工場廃水の活性炭処理法に関する基礎的実験を行い，処理上の一般的様式に就いて検討した。

2．活性炭の処理可能液量は廃液の種類及び石炭酸濃度，濾過速度，活性炭の大きさ等によつて影響される。

3．活性炭の大きさは粒径0.5～1 mmが適当である。

4．濾過速度は活性炭1屯当り20～30m³/時が適当である。

5．活性炭の再生に要するベンゼンは50m³/屯である。

6．再生活性炭の石炭酸吸着能力は再生回数に関係なくほぼ一定である。

7．供試活性炭の供試廃水に対する処理可能液量は炭粒径0.5～1 mm，濾過速度25m³/時に於いて約100m³/屯である。

8．活性炭の最小必要量（X屯）は下記の式によつて算定することが出来る。

$$X = \frac{\frac{V}{B}}{M} \quad \cdots\cdots(1) \qquad B = \frac{24}{T + t} \quad \cdots\cdots(2) \qquad T = \frac{\frac{V}{B}}{S \cdot X} \quad \cdots\cdots(3)$$

但し，Vは廃水量（m³/日），Mは再生活性炭の処理可能液量（m³/屯），Bは1日間の最大処理回数（回），Tは1回の処理に要する時間，（時間），tは活性炭の再生に要する時間（約2時間），Sは濾過速度（m³/屯・時）である。

文　　献

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海産腹足類の卵仔に関する研究—I※

カニモリガイ，カゴメガイ，シラゲガイ，ムギガイ，オハグロシヤジク

網尾　勝

Studies on the Eggs and Larvae of Marine Gastropods—I

By

Masaru Amio

The eggs and larvae of five species of marine gastropods, which are found off the coast of Yoshimi, Yamaguchi Prefecture, are described in this report. The results of the writer's observation are as follows.

Cerithium kochi (Fig. 1. a～e).

The egg-filaments (1.0～1.5mm in diameter, 60～90cm in length) are spawned, covered with sand and tangled at the bottom of shallow waters. In this filament, a very fine canal is visible in the state of an irregular coil. Each capsule (0.17mm ×0.14mm in diameter) contains one ovum (0.10mm in diameter), and is arranged in a row in this fine tube. The embryo reaches the free-swimming veliger stage in ten deys at 23～27°C. The larva has a slightly pitted shell (0.16 mm across), a two-lobed velum, clear otocysts and two indistinguishably small eyes, but no tentacle. The breeding season extends from June to August.

Bedevina birileffi (Fig. 2. a～j).

The egg-capsule is like a very thin lens in shape (about 3.0mm in diameter, 0.90mm in hight), and contains about 60 to 90 ova (0.19mm in diameter) tinged with orange. 12 to 58 egg-capsules are placed in a group on the under-surface of egg-masses of *Neverita vesicaris*, surface of living adult shells, and inner surface of dead oyster-shells. About two weeks must be spent in hatching eggs at 23～27°C. A hatched veliger larva has a shell (about 0.31mm across) of fine spiny granulation. The digestive organ is of dark purplish tinge. Two eyes are recognized but the tentacle is seen only on the right side of the two-lobed velum. In three or four days after being hatched, the velum becomes four-lobed. The veliger larva metamorphoses when the shell is about 0.90mm in height after the pelagic life for about a month. The egg-capsules are collected in June or July.

Pyrene lischkei (Fig. 3. a～d).

※ 水産講習所研究業績 第237号，1957年7月25日 受理

Drum-shaped egg-capsules (about 0.75mm in height, 1.80mm×1.60mm in diameter) are laid on *Zostera* leaves in one or three rows. The ridge, possibly a vestigial membrane, surrounds the cylindrical trunk under the collar-like membrane surrounding the exit hole. One egg-capsule contains one or three ova (0.39mm in diameter). The larva (0.85mm in shell height) leaves the egg-capsule in about a month in the crawling stage, and has a smooth, light yellow or brown shell. The breeding season extends from April to July.

Mitrella bicincta (Fig. 4. a～e).

Spawning adults were caught in December, 1956. Their egg-capsule is identified with that of *Columbella* (? *versicolor*) belonging to the same family which has been described in the writer's previous paper[1]. The spawning season extends from December to March in their lowest temperature. The zygots, 9 to 60 in a capsule, spend about a month in getting hatched at that time. The veliger larva (about 0.30mm across) leads a pelagic life for more than 20 days.

Clavus japonicus (Fig. 5. a～f).

Helmet-shaped capsules (about 1.7mm in height, 2.3mm in diameter) one to fifteen in number, are attached solitarily to a living shell of *Cerithium kochi*. Two to four yellow tinged ova are seen in a capsule. The embryos, in the stage of blastula, leave the egg-capsule in the crawling stage after the period of 20 to 25 days (at 23～27°C.) when the shell is about 1.2mm high. A hatched larval shell is smooth and brown. In a few days after hatching, a slight sinus appears at the upper portion of the outer lip, and a large longitudinal rib is seen in the grown part of the shell. The egg-capsules are collected in June and July.

緒　　言

海産腹足類には水産上の有用種のみならず，有害と見做される種類が可成り多く含まれているが，この類は分類学上並びに生態学上不詳の点が多く残されている。特にこの類の産卵の状態や幼期の形態及び生態に関する研究が分類学上重要な貢献を果し[illegible]，或は直接その増殖に当つて効果を挙げ又有用貝の害敵駆除[illegible]等に於いても必要な事柄であることは論を俟たないところであるが，邦産種に於いてはこれに関する知見が甚だ少ない。

この現状に鑑み，筆者は既に高都に於いて Naticidae, Pyrenidae, Nassariidae 等に属している幾つかの貝類が産出する卵，及びこれ等が孵化する幼生に就いて述べたが，今回は下関市吉見附近の沿岸で採集した Pyrenidae に属する2種，Muricidae, Cerithiidae, Turridae 等に含まれる各1種に就き報告する。採集した卵塊は，室内で1～2日毎に換水して発育経過を調べ，同時に野外に於ける産卵，産出された時の状況及び卵の発育等についても併せて観察を行つた。一種の同定に当つては筆者が主に Naticidae 等で行つたと同様，孵化した幼生の殻形及び軟体部と成貝の貝殻部及び軟体部等を比較し検討を加えた。又この外に，水槽中での産卵や，野外で産卵中のものを観察することにより正確を期した。

本文に先立ち御校閲を仰いだ当所吉田裕博士に深甚の謝意を表する。

観　察　結　果

1. カニモリガイ *Cerithium kochi* PHILIPPI (第1図. a～e).

産卵場所：水産講習所前の海岸では大潮時の干潮線下水深20cm～2m位迄の砂上に産出されている。附近には周年親貝が認められるが，産卵期には多くの親貝が産卵場所附近に集つて来て，浅く砂中を潜入したまま匍匐しているのが見掛けられる。この場所は附近でも砂質は荒く，泥分の比較的多く混つている場所には産出されていない様である。

産卵期：1956年6月22日の採集では十数個の卵塊が得られたが，この中には既に孵化しつつある卵塊もあり，又卵の分割初期に相当するものや親貝の産卵中のものも認められた。6月初旬には未だ産卵が見られなかつたし，後述する孵化に要する期間等の点から考えて，6月中旬頃の海水温度23°C 前後から産卵が始まるものと推測される。その后7，8月中にも引続き卵塊が見られたが，9月に入ると認められなかつた。

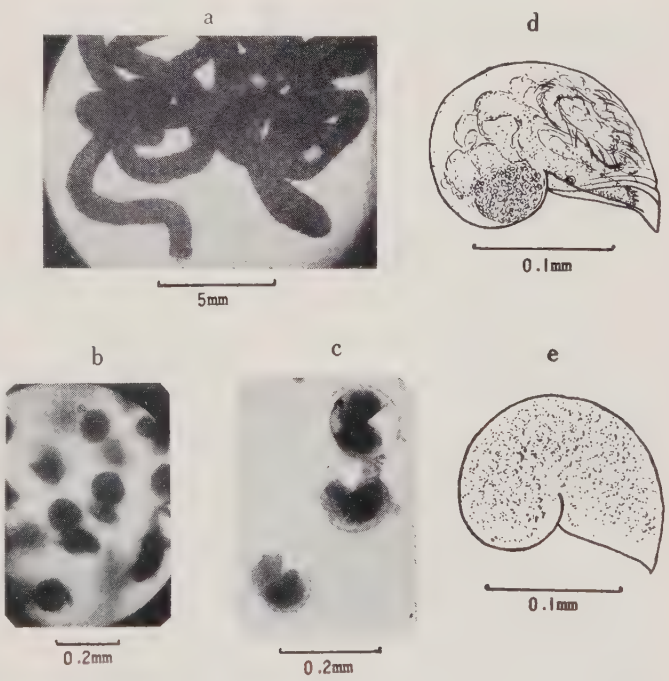

Fig. 1. *Cerithium kochi* PHILIPPI. a, Egg-filament; b, fine canal and egg-capsule in egg-filament; c, veliger stage before hatching; d, e, free-swimming veliger and its shell.

卵塊の産出状態：採集時の観察では親貝は浅い水底の砂上を匍匐し乍ら体の右側前方から砂をまぶした紐状の卵塊を産出する。産み終つた卵塊は一端が砂中に浅く埋没し，軽く粘着している。全体の外観は恰も蕎麦を盛つた様な状態を呈し，ちぢれてもつれ合つたまま一塊になつて砂上に放置されている。

卵塊及び卵：卵塊は直径約1.0～1.5mm，長さ約60～90cmの細長い所謂卵紐である。紐の表面は附着した砂粒で掩覆せられ，この中に透明なゼリー状物質に包まれた更に細い透明な管が不規則なコイル状となつて存在している。この細管の中には個々に独立した卵嚢が一列に入つている。産出当初の卵嚢は直径0.17mm×0.14mmの鶏卵状，透明な嚢膜で卵の発生段階が進むにつれて幾分膨大する。卵嚢中には透明な粘稠液と共に直径0.10mmの極く淡い黄色を帯びた卵が1個宛入つている。この卵塊の外観はハナタリ[5]等とよく似た類型のものである。1mm当りの平均卵数から計算すると1塊の総卵数は約5～9万粒で甚だ多い。

幼　生：6月22日の分割初期の卵を含む卵塊からは室内で7～10日の間に殆んど全部の幼生が被面子となつて孵出した。この間の水温は23～26°C 位であつた。孵化当初の殻の直径は

約 0.16mmで，淡い赤褐色を帯び表面は粗面状，外唇中央部は幾分突出している。面盤は2葉型で中央附近には触角は認め得なかつた。又両眼は極く僅かにその存在を認知し得る程度で，よく注意しないと見落すおそれがある。内臓は淡黄色を呈し，消化器官等にも特に濃い色素は認められない。面盤周縁の纖毛は比較的長く，幼生は極めて活潑な游泳を行う。足部後端は稍円鈍，背面の蓋は丸く大きい。1週間以内に殆んど全部の幼生が斃死したので，変態する迄の期間は不明であるが，この間に於ける幼生には大きさ形態共に著しい変化は認められなかつた。孵化幼生の右側面の形と成貝の胎殻部上面の形はよく合致する

2. カゴメガイ *Bedevina birileffi* (LISCHKE)　(第2図. a～i).

産卵場所：卵嚢は下潮線下水深1～2m位の所に産出されているヒメツメタ[2]　の卵塊（砂茶碗）の裏面や，垂下して水底に接している金網籠内のカキ死殻の内側面等に多数見受けられる。時にはアラムシロ[3]　の場合で認められたと同様，同種の生きた成貝（雌雄の差別はない）の殻表にも産卵している。親貝はカニモリガイの産卵場所よりも若干泥分の多い所に棲息している様で，産出卵もこの附近に多い。卵嚢の附着している箇所は親貝の表面を除けば何れも直接表面からは見えない多少とも陰蔽されている所であり，これは附近に認められる近縁種イボニシ，レイシ等が露呈した面上で多数産卵しているのを見掛けるのと異つた現象である。

産 卵 期：1955年6月21日にはヒメツメタの卵塊の裏面に産卵中の親貝を発見した。附近で同時に採集した卵嚢の中には担輪期のものや分割初期のものも認められ7月下旬では孵化后で空になつている卵嚢が多かつた。翌年にも6，7月の頃卵嚢が採集されたから恐らくこの頃が産卵盛期であろうと推測する。

卵嚢の産出状態：卵嚢は1個所に12～58個，普通20～30個が連続した1群となつて産出されている。殆どの場合卵嚢は極めて不規則に並んでいて，各卵嚢は何れも隣接して各付着盤の遊離縁で，相互に接着していて個々には分離しない。時には1，2個の卵嚢が主群と若干離れて産出されている場合もあつたから，卵嚢は個々に親貝から産出されるものと思う。イラン湾の *Drillia crenularis* [10]　も砂茶碗の裏面や他の死殻上に産卵し，本種と卵嚢の型や産卵場所が類似している

卵嚢及び卵：卵嚢は高さ 0.80～0.90mm，直径3.0mm前后の甚だ扁平な形を呈し，表面中央部に直径0.40～0.46mm×0.58～0.62mmの孵出孔が存在する。附着盤には巾約0.35mmの遊離縁が認められ，孵出孔を挾んで基底に達する2本の龍骨は不鮮明である。卵嚢は内外両側嚢が認められ，外側嚢は半透明の比較的薄い膠質様物質である。僅かの間隙を残してこれに内接している内側嚢は極く薄い透明な膜質で，その中に粘稠液と60～90個の淡いオレンジ色の卵とが含まれている。邦産種では未だ本種の卵嚢と似た類型のものは知られていないようであるが，外国産では先の *Drillia* の他大西洋産 *Urosalpinx*, *Cantharus* [9]　等に属する種類に見られ，何れも附着物が不安定である点も類似しているようである。卵の直径は 0.19mmで，近縁のオオウヨウラク[4]　等で記載されている様に孵化迄に卵数が減少する現象は認められなかつた。

幼　生：6月21日分割初期にある卵を内包する卵嚢群は6月28日頃担輪期，或は初期被面子期に進み，7月2日から7月8日の間に殆ど全部が孵化した。即ち孵化期間は水温 23～27°C位の範囲で凡そ2週間である。孵化時の殻の大きさは径 0.30～0.32mm，表面には微小な粒子が幾分粗に分布している。然しこの微粒子は，本種と甚だ類似した被面子をもつアカニシ，イボニシ，レイシ等の微粒子と異つて粒子の先端が尖つていて，この状態は幼生の成長と共に

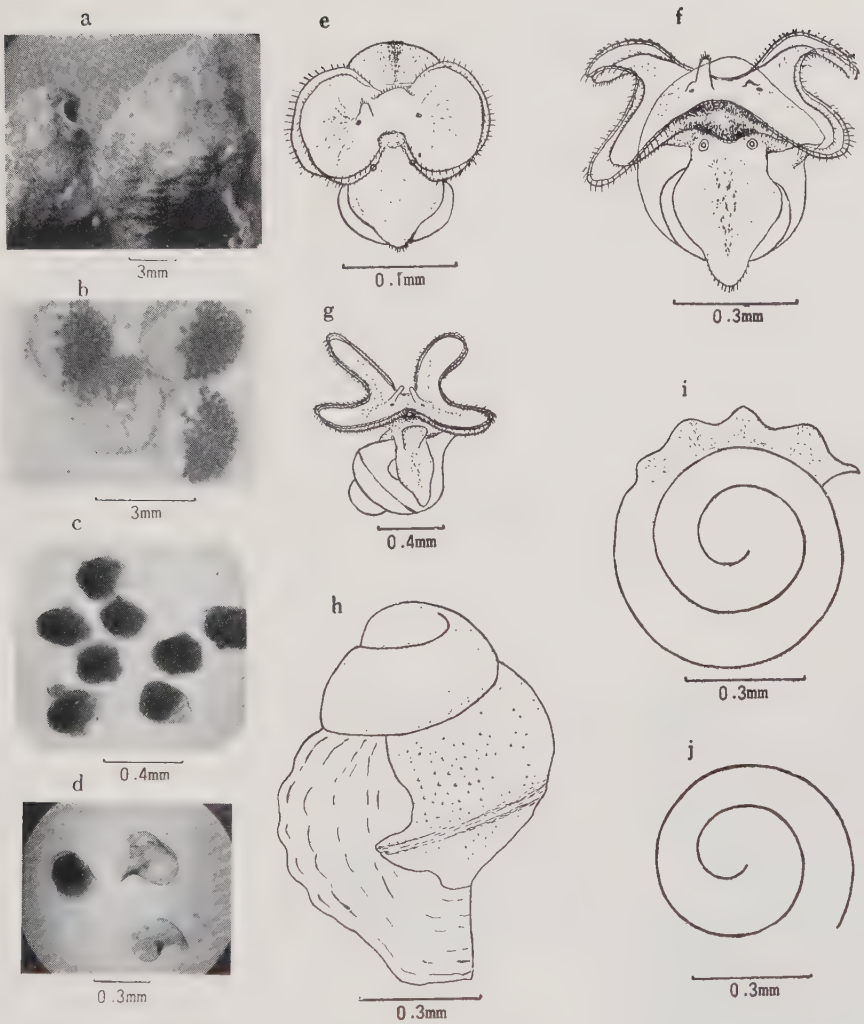

Fig. 2. *Bedevina birileffi* (LISCHKE). a, Egg-capsules attached to parent shells; b, separated egg-capsules containing embryos; c, rotating embryos in egg-capsule d, shells of free-swimming veliger; e, newly hatched veliger larva; f, free-swimming veliger, 13 days old (0.63mm across); g, free-swimming veliger, 18 days old (0.78mm height); h, i, lateral and apical aspects of larval shell, after metamorphism; j, apex of adult shell.

益々顕著に認められる。孵化当初の面盤は2葉型，眼は左右共明らかであるが，触角は上記3種と同様右側のみに認められ，比較的短かく太い。肝臓部は稍濃いオレンジ色，消化管の部分は濃い紫黒色を呈する。足の根元附近は暗色を帯び左右には平衡胞が認められる。足部後端は三角形，末端には数本の棘状毛を備え，背面には薄い蓋を有つ。孵化後3～4日間（殻径0.38mm）外唇中央部は可成り突出し，水管溝も発達した。この頃から面盤は4葉型となつた。13日后には殻径及び殻高は略等大となり約0.63mm，1$\frac{3}{4}$殻階を示した。面盤の各葉は益々長大となり水管溝，軸部の茶褐色は濃い。足部後方からは上述3種と同様糸状の粘質物を長く引き乍ら游泳する。この時期になると左側の触角も次第に突出し始め，殻高0.78mmでは既に両

側に備わり，前足部の発達も漸く顕著に認められるようになつた．幼生は静止した水中では大きな面盤を拡げて繊毛を動かすだけで活潑な游泳は行わない。20日后殻高 0.81mm（約2殻階）に成長し，面盤は未だ存在するが底面を匍匐運動するのが時々観察された。約1ケ月后，殻高 0.96mm，殻径 0.70mmに達した幼生は完全に面盤を失つて匍匐生活に移つた．殻高 0.90mm 附近からは体層中央部の1本の螺肋及び棘状の粒子は消失し，代つて鈍い縦肋が出現している。殻色も全体的に急に濃い茶褐色を呈し新たに4～5条の螺肋も出現して成貝の形に近づく。水管溝から出る水管はムシロガイ類程には長くはない。匍匐幼生の前足は円鈍でムシロガイ類やバイの幼生のように糖状を呈せず運動速度も鈍い。先に挙げた外国産の本種に類似した卵嚢から孵化する幼生のほとんどの種類が自由游泳期を缺くに反し，本種は邦産上述の3種とよく似た初期生活を行い游泳期間が比較的長い点は特異である。孵化幼生の殻と成貝の胎殻部とはよく合致する。

3. シラゲガイ *Pyrene* (*Indomitrella*) *lischkei* (SMITH)　(第3図. a～d).

産卵場所：本種の卵嚢は干潮線附近の極く浅い所に密生するアマモの葉面に多数認められた．又親貝は動揺する葉面に附着したまま産卵を続けていた。アマモ附近にはカニモリガイやムシロガイ類と一緒に親貝が棲息しており，野外ではこれ以外の場所からは卵嚢は認め得なかつたが，室内では水槽内の側面にも数個産卵した。

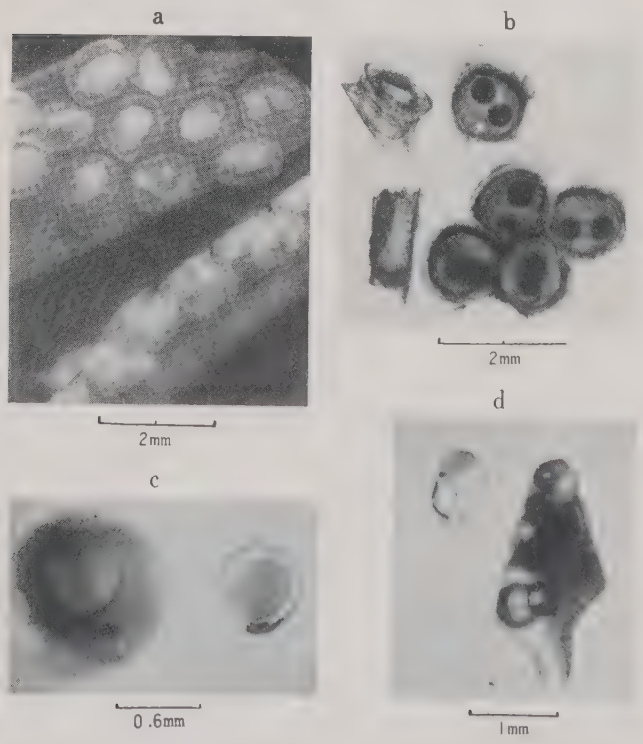

Fig. 3. *Pyrene lischkei*(SMITH). a, Egg-capsules attached to *Zostera* leaves; b, separated capsules and eggs in capsule; c, apical aspect of larval and adult shells; d, lateral aspect of larval and adult shell.

産卵期：1955年から '57年に亘る観察では4月上旬から7月迄卵嚢が見掛けられ，特に5月中旬から6月中旬頃には盛に産卵しているのが見られた。即ち野外では水温 14°C 位から産卵が始まり 18～24°C 位が盛期に相当する．

卵嚢の産出状態：1個体に4～20個位，普通十数個の卵嚢が稍不規則な1～3列の列状となつて相互に接着して産出されているから1個体の産出卵嚢数も略この位であろうと推測する。然し水槽中では個々に離れて産出されていた。産卵初期では1群の卵嚢数は比較的少なく，盛期には多くなる傾向が認められた。卵嚢を附着物から剝離することは難しい。

卵嚢及び卵：卵嚢は本科の2，3の種類[1, 10]で記載されているように孵出孔周辺を取り囲んでカラー状の膜が存在し，邦産

のムギガイ(後述する)，マルテンスマツムシ*等と類似の卵嚢である。外観は太鼓型で，高さ約0.75mm，径約1.80mm×1.60mmの不規則な楕円状を示す。基底部の遊離縁は0.30～0.50mm，孵出孔は0.64～0.80mm×0.96～1.30mmで可成り大きい。卵嚢本体の側壁には長軸方向に沿つて，孵出孔を挟む2本の明瞭な龍骨が存在する。孵出孔周縁のカラー状膜には多数の可成り規則的な皺条が認められる。ムギガイの卵嚢ではこの膜の下方，円筒状の卵嚢本体の中央附近に同様の膜が存在しているが，本種ではこれが痕跡的となり，僅かに隆起した畝状に認められるに過ぎず，これが円筒状の卵嚢本体を囲繞している。卵嚢を構成する嚢壁(外側嚢)は，略透明でムギガイよりも幾分厚い寒天状の物質であり，内接する透明な薄い内側嚢には粘稠液と共に1～3個，普通2個の卵が包含されている。卵は淡黄白色を呈し，その直径は0.39mmである。

幼　生：1956年6月8日採集した産出后間もない分割初期の卵を内包する卵嚢群は，2週間前后経過して大部分は胎殻も出現して被面子期に進み，卵嚢内を動き廻るようになつた。22日前后経過したものでは面盤は消失し，孵出寸前の発達した幼生が認められた。約4週間以内に過半数の幼生が匍匐し乍ら孵出した(水温18～26°C)。孵化時の大きさは殻高0.83～0.93mm，殻径 0.60～0.63mmで2殻階余に達している。ただ1個の幼生しか認められない卵嚢からは殻高1.05mm位の大きい幼生が孵化した。これ等孵化幼生の殻色は同一卵嚢に於いても茶褐色の個体や，淡黄色の個体が混在し一様ではない。この中，淡黄色個体は，孵化後外唇新生部に濃い茶褐色斑が出現し，同時に鈍い縦肋を生じて成貝の特徴が出現して来る。本種の成貝の殻表の色彩も，この稚幼期に認められたような殻全体が茶褐色を呈するもの，或は淡黄褐色地乃至は網目模様地に規則的な濃い茶褐色斑を備える凡そ2通りが認められるから，同一卵嚢内で見られる幼生の色彩の変異は親貝から遺伝したものであろう。孵化幼生の足部は灰色を帯び触角は比較的長くその基部の眼は明らかに認められる。細長い足の背部には小さい蓋を乗せている。この幼生の軟体部はボサツガイ[1]　と比較的似ている。孵化した幼生の殻と成貝の胎殻部とはよく合致している。

4.　ムギガイ *Mitrella bicincta* (GOULD)　(第4図. a～e).

本種の卵嚢は先に筆者が *Columbella* (? *versicolor*) としたものであり，その時は成貝で胎殻を止めている個体が採集されずこれと比較検討することが出来なかつたので，一応疑問種としたものである。その後垂下中のアコヤガイの殻表で産卵中の親貝を捕えることが出来，同科に属する本種の卵嚢であることが判明したので追加補正する。

産卵場所：その後の調査ではアコヤガイ，ウミウチワ類の他にイガイ，アヅマニシキの殻表，ホヤ類の表面等に産出されているのが見受けられた。

産 卵 期：1955年には12月中旬から，1956年には11月下旬から産卵が認められ，何れも3月迄幼胚を内包する卵嚢が認められた。特に12月下旬，1月頃には垂下中のアコヤガイの表面で盛に産卵が見られ，この頃は年間で水温の最も低い時期に相当する。親貝は雄は概して小さく殻高8mm 前後，雌では 10mm 前後が普通で，この時期には生殖巣中には運動する精虫や，成熟した卵が認められる。

卵嚢の産出状態：極めて不規則に附着し，列状には産出されていないが普通20～40個位が1群をなしている。卵嚢は互に附着盤遊離縁で接着し，附着物からは容易に剝離されない。

卵嚢及び卵：卵嚢の形状は前報したので省略するが，邦産ではマルテンスマツムシ，シラゲ

* 本種の卵嚢は西海区水産研究所田中弥太郎技官から御恵送頂いた。記して深謝する。

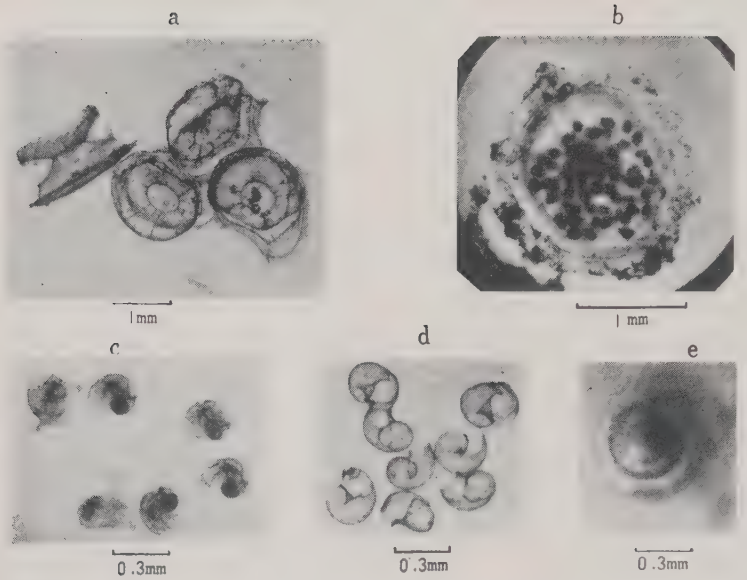

Fig. 4. *Mitllera bicincta* (GOULD). a, Empty egg-capsules ; b, under side view of egg-capsule containing inner capsule and embryos ; c, free-swimming veliger larvae ; d, shells of free-swimming veliger ; e, apex of adult shell.

ガイ等とよく似た類型のものである。多数の観察例では，甚だ大きさに変化が多く不揃である。又その中の卵数にも変異が多く最少9個から多いものでは60個位入つている卵嚢も認められた。卵の直径は0.14mmで殆んど変異はない。

幼　生：室内で数例観察した結果を総合すると，水温およそ8～14°C の範囲では産卵後4日間位で胞胚期に進み，更に4～5日後担輪期に進み，卵嚢内をゆるく廻転し始める。内側嚢とこの時期には外側嚢との間隙が明らかに認められるが，更に10日後胎殻及び面盤が生じて被面子初期に進み，肉眼でも幼胚が嚢内を動いているのが認められるようになると，膨大して殆ど外側嚢に内接するか，或は幼胚によつて破られてしまうので観察は困難となる。その後1週間位経過し食道部，腸部が紫黒色を帯び，殻表の微粒も明瞭に認められるようになつて，径約0.30mmの被面子が孵化する。即ち約1ケ月を要して孵出するのであるが，或る例では1月5日から3月13日に到る2ケ月余の間も卵嚢内に止まつていた。変態期に達する迄の期間は未詳であるが，2，3月頃では孵化後少なくとも20日間位游泳を続行する。幼殻と成殻の胎殻部とは合致している。

5. オハグロシヤジク *Clavus* (*Elaeocyma*) *japonicus* (LISCHKE)（第5図. a～f）.

産卵場所：本種の卵嚢は親貝のいる附近に棲息するカニモリガイの殻表に産出されている但し附着は殻の上側面（背面）に限られ，下側面には附着しない。尚このアマモの生えている附近の砂地には特別な地物は存在せず，親貝は附近の砂中に浅く潜入している。カニモリガイ以外には附着している例は見掛けられなかつたが，この卵嚢に類似した卵嚢の附着した他種のそれから推して，他の貝類の上にも産出される場合もあるものと思う。

産卵期：1956年6月22日に47個の卵嚢が得られたが，その中過半数は初期被面子期以前のものであり，若干孵化後のものも認められた。又7月上旬にも担輪期のものが採集された。後述する孵化に要する期間等から考えて，6月上旬頃から産卵が始まり7月中も産卵が行われるものと推測する。

卵嚢の産出状態：卵嚢は1個体のカニモリガイに1～15個が附着しているが，極めて不規則に個々に産出されていて時には卵嚢の一部が重なつている場合もあつた。然しカゴメガイ等で

認められたように相互の遊離縁で連接している状態は認められなかつた。8～15個が1個体に附着している場合でも幼胚の発育段階は多くても5～7個の卵嚢が略同程度の段階に達しているから，1回の親貝の産出数もこれ位に限られているものと思う。

卵嚢及卵：卵嚢の外側嚢は比較的厚い膠質状物質で構成され，ヘルメット型を呈し，直径 2.2～2.5mm，高さ 1.6～1.8mm 孵出孔の径 0.84～0.97mm×0.92～1.20mm，遊離縁の巾は約0.30mmであつた。この卵嚢は生きた貝類に産出されている同様な他種の例よりも相当大形である。卵嚢は他種の場合と同様内側嚢，粘稠液及び黄色を帯びた2～4個の卵が共に外側嚢の中に包含されている。孵出孔を挟んで存在する2本の龍骨は比較的明瞭に認められる。本種の卵嚢では，孵出孔を塞いでいる膜壁が残存しているに拘らず，卵嚢側面に小さい孔があけられていて中の幼胚が全然認められないものが可成り多かつた。この孔は孵化幼生の殻径よりも非常に小さく，又隣接する卵嚢の幼胚も比較的初期の発育段階のものが認められるので，幼生が喰い破つて出たものとは考えられない。恐らく他貝の歯舌によつて破られ，幼胚は哺食せられたものと思われる。分割していない卵の直径は約0.65mmで大きい。この卵嚢の型は欧州産[7,8]の同科のものや，西アフリカ産の *Drillia sp.*[6] 等と類似している。

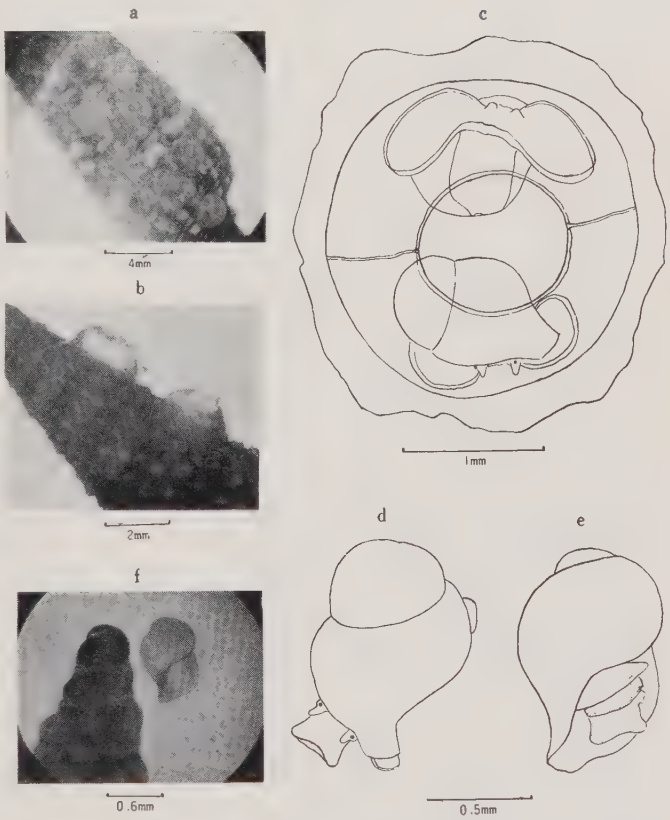

Fig. 5. *Clavus japonicus* (LISCHKE). a, Egg-capsules attached to shell of *Cerithium kochi*; b, magnified lateral aspect of capsules; c, veliger larvae in capsule; d, e, hatched larva after metamorphism; f, lateral aspect of larval shell and adult apex.

幼　生：胞胚期にある卵を含む卵嚢群からは水温凡そ 23～27°C の範囲で20～25日を経過した後，変態を終えた匍匐幼生が孵出孔から離出した。この幼殻の大きさは高さ約 1.2mm，巾約 0.80mm を示し，赤味を帯びた茶色で殻表は平滑である。匍匐幼生の触角はシラゲガイやボサツガイよりも短く，両眼は明らかに認められる。卵嚢離出後，外唇の新生殻部は急に著しく隆起して縦肋となり，出水部（後溝部）は多少切れ込み成貝の特徴が出現して来る。足は稍細長く前足部は幾分角張り運動は鈍い。胎殻は附近に産するマダラクダマキの胎殻部と外形は著しく類似しているが，これと違つてかすかな縦肋が早くから出現せず，又色彩も幾分異つ

ているので識別出来る。成貝の胎殻部は幼殻よりも濃い茶褐色を呈するが，孵化幼生の殻とよく合致する。

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日本海に面する山口県下吉見地区の貝類相※

吉田　裕・網尾　勝・野島重昭

Shell Fish Fauna in the Japan Sea off Yoshimi in Yamaguchi Prefecture

By

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Concerning the faunal area of shell fish, the Japan Sea may be divided into three parts located in lat. 35° N, lat. 41° N and lat. 46° N, respectively (Fig. 1). The shell fish fauna of Yoshimi district much resembles that of Onomichi in the Inland Sea of Seto which is adjacent the former. In these districts, the southern species are predominant, in number, coming next to the species which inhabit both southern and northern districts, but the northern species do not appear (Table 1). Also, the species occurring in Yoshimi district are 69.0% similar to those of Onomichi, and 80.5% similar to those of Wagura, Noto Peninsula (Table 2). The above-mentioned faunal area of shell fish in the Japan Sea agrees well with the conditions of ocean currents. The Tsushima Warm Current runs northward along the coast of the Japan Sea, warming the sea especially to the south of Shimane Prefecture. This makes us draw a remarkable line of distinction in the shell fish fauna between Shimane and Noto Peninsula. The branches of the current come up to the north passing the Straits of Tsugaru and Soya, showing the limit of distribution of shell fish in the northern Japan Sea.

緒　　言

本所の所在地吉見地区は日本海に面する本土の南端に近く，直接対馬暖流に洗われると共に，瀬戸内海とも区域を接するため，海況上その影響も免れ得ない地区である。従つて海産生物相もそれらの海況に相応じた様相を呈しているであろうことは想像に難くない。よつて先づその点を明らかにして置くことは此の地にあつて今後海産生物を対象として生態的或は応用的の諸問題に関する研究を進めて行くためには先づ第一に手をつけておかなければならないことである。此のような考えに基き筆者等は先に此の地区の魚類相[1]につき報告したが，今回は貝類相について検討を試みた。先づ日本海全体の貝類相につき考え，次に吉見地区の状態を日本海の他の部分及隣接する瀬戸内海の状態と比較検討した。

※水産講習所研究業績 第238号，1957年7月25日 受理

日本海に於ける貝類分布区の区分

日本海全体に亘る貝類相を検討するため，黒田・波部両氏 (1952)[2] によつて日本海から記載された而かも分布の北限が判然としているもの 1275種，南限が判然としているもの 1280種を拾い，緯度1度毎にその分布を分けると第1図の通りである。即ち南から北に亘つて分布する種類の北の限界は先づ，島根県の江津附近 (35°N) から能登半島の中部 (37°N) に最大の山があり，次いで津軽海峡 (41°N)，宗谷海峡 (46°N) と相当歴然とした山が相次いでいる。北から南に亘つて分布する種類の南の限界は，江津附近 (35°N) に著しく明瞭なものが見られ，秋田県八郎潟附近(40°N)，宗谷海峡(46°N) には共に不顕著ながら山が見られる。更にそれら南限及北限の両方を併せて，日本海全域に亘る貝類分布上の大きな区分を求めると，35°，41°，46° にその限界を認めることが出来るが，その中でも35—37°N に南北の最も顕著な限界を見る。依つて，南から北に亘つて分布する種類で，分布の北限が36°N以南にあるものを南方種 (S)，北から南に亘つて分布する種類で分布の南限が37°N 以北にあるものを北方種(N)，それらの限界を越えて分布するものを共通種(T)とすれば，各S－395種，N－190種，T－690種となる。

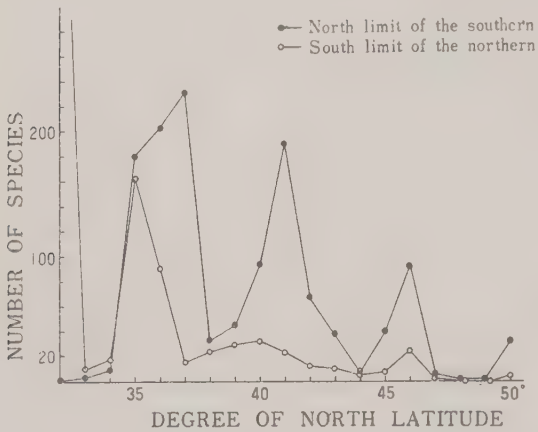

Fig. 1. Showing the limit of the distribution of the shell fish on the coast of the Japan Sea.

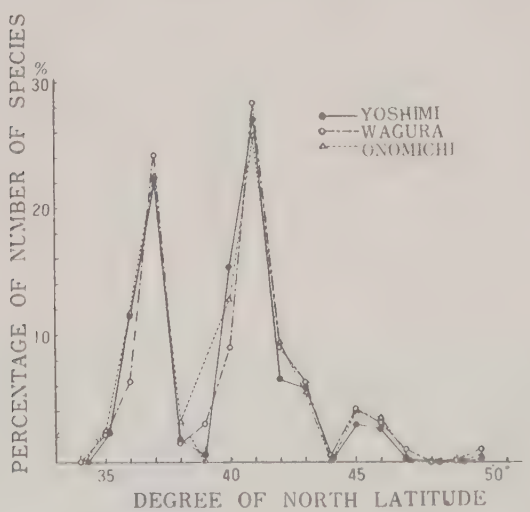

Fig. 2. Comparison of the limit of the distribution of shell fish in Yoshimi district with Wagura (the NotoPeninsula) and Onomichi (the Inland Sea).
Remarks : Only the north limit of the southern species.

吉見地区と他の地区に於ける貝類相の比較

吉見地区の貝類相を他の地区のそれと比較するため，筆者等が吉見地区で採集調査した資料と能登半島の和倉 (伊藤，1954)[3] 及吉見に隣接する瀬戸内海の尾道 (滝，1936)[4] の状態と比較した。吉見302種，尾道218種，和倉189種につき南から北に亘つて分布する種類の北の限界を図示すると第2図の通りで，大体海浜で容易に採集される種類が主であるため図のように一致の傾向が強いが，3地

区共貝類相は極めて類似しているといえよう。次に以上の3地区に於ける南方種，北方種，共通種の比率を比較すると第1表の通りで，3地区共共通種が最も勝り，次いで南方種が優勢である。吉見及尾道は特に類似し，共通種及南方種の比率も極めて近似し，共に北方種は見られない。和倉ではそれらに較べると南方種の比率が減り，僅かではあるが，北方種も現われている。

次に吉見，尾道，和倉各地区の状態を主体（上欄）として，各吉見，尾道，和倉（左欄）の状態と比較すると第2表の通

Table 1. The faunal distribution of shell fish in various localities of the Japan Sea.

Loc.	Item	S	T	N	Total
Wagura	No.	15	172	2	189
	(%)	(7.9)	(91.0)	(1.1)	(100)
Onomichi	No.	30	188	0	218
	(%)	(13.8)	(86.2)	(0)	(100)
Yoshimi	No.	42	260	0	302
	(%)	(14.0)	(86.0)	(0)	(100)

Remarks : S Southern Japan form; T Through out Japan form; N Northern Japan form.
Expecting the species described only Pacific regions in check list (KURODA and HABE, 1952).

Table 2. Comparison of species concerted in each locality.

Loc. (1) / Loc. (2)	Yoshimi		Onomichi		Wagura	
Yoshimi	66(19.5%)	104(31.0%)		194(70.8%)		135(62.0%)
Onomichi		231(69.0%)	169(61.6%)	80(29.2%)	102(46.8%)	
Wagura	269(80.5%)		105(38.4%)		116(53.2%)	83(38.0%)
Total	235(100%)		274(100%)		218(100%)	

Remarks : Loc. (1) Subject; (2) Object.

りである。ここでは吉見地区で採集されたもので，和倉（伊藤），尾道（滝）の目録に挙げてないが，全日本（黒田・波部）の目録に依れば当然その地区に分布していると思われる種類は，比較の便宜上夫々和倉及び尾道の種類の中に加えて扱つた。その結果，吉見地区に於ける同一種の分布状態は尾道とは69.0%，和倉とは80.5%，尾道では吉見と70.8%，和倉と38.4%，和倉では吉見と62.0%，尾道と46.8%共通である。従つて吉見は尾道よりも和倉，尾道は和倉よりも吉見との関連性が強く，和倉もまた尾道よりも吉見と関連性が強い。

日本海の貝類相と海況との関連

筆者の一人吉田（1957）[1] は魚類の分布上日本海を3区に分け，その状態がよく日本海の海況と関連することを述べたが，筆者等がここに述べる貝類相もまた日本海の海況と関連性が強い。即ち日本海沿岸を南から北に北上を続けている対馬暖流の勢力は，特に島根以南では卓越し，周年暖流系の水を湛えていることは，南から北に亘つて分布する貝の種類の北限が島根県江津附近から能登半島の間に最も多く存在することとよく一致する。対馬暖流は更に北上を続け，津軽海峡及び宗谷海峡に這入り込んで，ここで夫々支流を形成していることは，津軽及び宗谷の両海峡の部分に貝類分布上の顕著な限界が見られることとよく合致する。これらの状態

はまた滝庸氏 (1939)[5] が説くところとも一致する。

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ドジョウの増殖に関する研究 -I

種苗の魚体の大きさが生産量に及ぼす影響※

久保田善二郎・松井　魁・白羽根元二・吉武嘉甫

Studies on the Reproduction of the Loach, *Misgurnus anguillicaudatus* (CANTOR)—I
The Influence upon the Productivity due to the Size of Fry

By

Zenziro KUBOTA, Isao MATSUI, Genzi SHIRAHANE and Yoshio YOSHITAKE

It is of importance to select the fry so that the fish can be plentifully produced. MATSUI (1936 & 1952) mentioned that the eel culture technique is closely related with variant degrees of the size of the body at the fishing time and a group of the fry with greater variant degrees in the size at the planting time are inferior to another with smaller variant degrees,so far as the weight-multiplication rate, food coefficient and decreasing rate are concerned. In the present experiment the authors have investigated in their first experiment on the loach the influence of the size of the fry on the productivity, and in their second experiment the influence of variant degrees on the productivity.

1) The weight-multiplication rate is higher in large-sized fish than in small-sized ones.
2) The decreasing rate is higher in small-sized fish than in large-sized ones.
3) The food coefficient is smaller in younger fish than in older ones.
4) The variant degrees in the size of the fish have no influence on the productivity.

緒　　言

魚を，より多く生産する為には，種苗の選択が重要である。松井[2)3)]によれば，養鰻技術は，収納時に生産される魚体の大きさの変異度と密接な関係があり，又，放養時の種苗の大きさの変異度の大きい群は，小さい群に比較して増重倍率，飼料係数，減耗率等，養鰻技術を支配する諸要素が劣るとした。本実験ではドジョウを用いて，第1実験では種苗の魚体の大きさが，又，第2実験ではその変異度が生産量に及ぼす影響に就いて夫々研究した。

材料及び方法

供試魚は，第1実験では '56年7月28日に下関市吉見町永田川及びそれに附帯する溝で採捕

※ 水産講習所研究業績第 239号，1957年7月25日 受理

した当才魚を，又，第2実験では '55 及び '56年 の各6～7月に前記の場所で採捕，又は人工孵化した稚魚を，下記の養魚池で飼育した2才及び3才魚を夫々使用した。

実験池はコンクリート製で，長さ 190.5cm，幅 92cm，底部は排水口に向つて4cm傾斜し，その排水口に隣接して直径35cm，深さ 6 cm の魚溜りを有する水産講習所の養魚池を，第1実験では2面，第2実験では4面を夫々使用した。

実験期間は，第1実験では '56年7月30日より10月18日迄の 80日間で，この期間を4区に区分して，I期を7月30日～8月18日，II 期を8月19日～9月8日，III 期を9月9日～9月28日，IV期を9月29日～10月18日とした。又，第2実験では '57年4月16日より6月14日迄の60日間で，この期間をI期，4月16日～4月30日，II 期，5月1日～5月15日，III 期，5月16日～5月30日，IV 期，5月31日～6月14日に区分した。

実験方法は，第1実験では，大型魚（1.2～2.5g）からなるA群，小型魚（0.1～0.6g）のB群を夫々の池に24.8g宛放養し，20日毎に取揚げて総重量及び尾数を測定し，放養密度を補正することなく，その儘再放養して実験を継続した。実験開始時に於ける両群の詳細は第1表の通りである。第2実験では，A群は3才魚のみからなる15尾，147.5gを，B群は3才魚，8尾，74.5gと2才魚，34尾，72.4g との混合魚群からなる 146.9gを，a群は2才魚の中で比較的成長の良好な個体(3.0～7.4g)，15尾，61.6gを，そしてb群は2才魚の成長の遅い個体(0.6～1.8g)，27尾，31.9gと，成長の早い個体 (3.0～6.2g)，7尾，31.9gとの混合魚群からなる 61.5gを夫々の池に放養し，15日毎に取揚げて，第1実験と同様な項目に就いて調査を行い，A群とB群，a群とb群とを増重倍率及び餌料係数並びに減耗率に就いて夫々比較を行つた。第2実験に使用した供試魚の詳細は，第2表に示す通りで，変異度は体長，体重共にA群及びa群に比較してB群及びb群が僅かに大きい。

Table 1. Specimens for experiment 1.

Group	Amount of culture		Individual body weight (g)
	Weight(g)	Number of individuals	
A	24.8	13	1.91
B	24.8	79	0.31

Table 2. Specimens for experiment 2.

Group	Body length			Body weight			Amount of culture	
	Mean value	Standard deviation	Variant coefficient	Mean value	Standard deviation	Variant coefficient	Weight (g)	Number of individuals
A	10.70±0.10	0.56±0.07	5.20±0.64	9.89±0.29	1.67±0.03	16.93± 2.15	147.5	15
B	7.57±0.18	1.73±0.13	22.80±1.76	3.57±0.31	3.00±0.22	84.01± 9.58	146.9	42
a	8.05±0.09	0.49±0.06	6.11±0.75	4.15±0.27	1.52±0.19	36.65± 5.10	61.6	15
b	6.05±0.15	1.32±0.11	21.74±1.85	1.87±0.18	1.53±0.13	82.16±10.28	61.5	34

投与餌料は蚕蛹と米糠とを乾燥重量比，2：1の割合に混じて煮沸したものを，練固めて磁製皿に入れ，更にその皿は，摂餌運動による餌料の散乱を防ぐ為に池中に予め用意された直径23.5cm，深さ 8.5cmの洗面器の底に安置した。餌料は乾燥餌料にして，放養魚体重量の$\frac{1}{10}$量を1日1回，午前中に投与し，その残存餌料は乾燥器で水分を除去して後，秤量し，摂餌量を求めた。

増重倍率（W），減耗率（N），餌料係数（F）は次式に依つて求めた。即ち放養時の重量を w_0，尾数を n_0，収納時の重量を w_1，尾数を n_1，飼育期間中の総投餌量を f で表すと次の通りである。

$$W=\frac{w_1-w_0}{w_0},\quad N=\frac{100(n_0-n_1)}{n_0},\quad F=\frac{f}{w_1-w_0}$$

飼育期間中の週平均水温，は，第1実験，第1図第2実験，第2図に夫々示した。

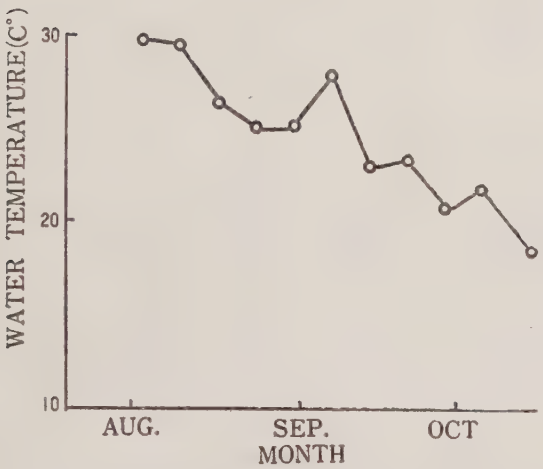

Fig. 1. Variation of water temperature during the period of experiment 1.

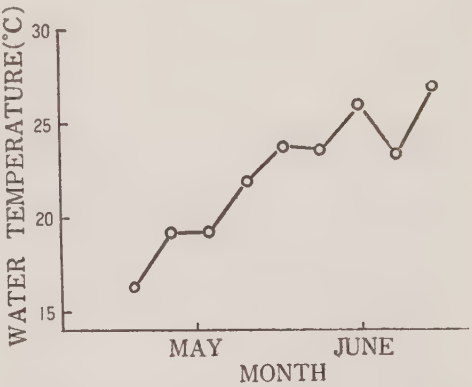

Fig. 2. Variation of water temperature during the period of experiment 2.

実 験 結 果

第1実験　種苗の大きさが生産量に及ぼす影響

実験結果は第3表に示す通りである。この表から増重倍率，餌料係数，減耗率，平均個体増重倍率を求めた（第4表）。

Table 3. Results of experiment 1.

Group	Date	At time of fishing		Average weight(g)	Increase of weight(g)	No. of decreased	Amount of food(g)	Feeding period (days)
		Wegiht(g)	Number					
A	Aug.18	37.5	13	2.88	12.7	0	19.5	15
	Sep. 8	52.4	12	4.37	14.9	1	41.0	18
	Sep.28	61.3	12	5.11	8.9	0	43.3	17
	Oct.18	62.0	12	5.17	0.7	0	38.8	16
	Total	62.0	12	5.17	37.2	1	142.6	66
B	Aug.18	42.0	76	0.55	17.2	3	26.4	15
	Sep. 8	60.0	61	0.98	18.0	15	60.5	18
	Sep.28	72.7	59	1.23	12.7	2	62.4	17
	Oct.18	81.3	55	1.48	8.6	4	70.4	16
	Total	81.3	55	1.48	56.5	24	219.7	66

Table 4. Relation between the size of fry and the weight—multiplication rate, food quotient and decreasing rate.

Date	Weight-multiplication rate (W)		Food quotient (F)		Decreasing rate (N)		Weight-multiplication rate in individuals	
	A Group	B Group	A Group	B Group	A Group	B Group	A Group	B Group
Aug. 18	0.51	0.69	1.54	1.53	0	3.79	0.51	0.77
Sep. 8	0.39	0.43	2.75	3.30	7.69	19.74	0.52	0.78
Sep. 28	0.17	0.21	4.86	4.91	0	3.28	0.17	0.26
Oct. 18	0.01	0.12	55.44	8.18	0	6.78	0.01	0.20
From July 30 to Oct. 18 (80 days)	1.50	2.28	3.83	3.88	7.69	30.37	0.30	0.50

各期間中の増重倍率は，何れもB群の方がA群よりも高率を示し，全期間を通じての増重倍率はA群 1.50に対してB群 2.28で，顕著な差異がある。増重倍率と飼育日数との関係は，日数の増加に伴つて倍率が減少する傾向を示す。

餌料係数は第III期迄，両群間に大きな差異を有しないが，第IV期ではB群，8.18に対して，A群，55.44で顕著な差異があり，全期間を通じての餌料係数はA群3.83に対してB群3.88で，略々同一の値を示した。餌料係数と飼育日数との関係は，日数の増加に伴つて係数値が大きくなる傾向がある。

減耗率は各期間共に，B群の方がA群よりも高率を示し，全期間を通じてのその値は，A群7.69に対してB群30.37を示し，顕著な差異がある。第II期の減耗率は両群共，他の期間と比較して特別に高率を示した。この原因は，同時期の水温が異常に高いことに依るものと考えられる。

個体の平均体重の増加量は，A群3.26 g に対してB群1.17 g で前者の方が後者よりも大きい。

個体の増重倍率と調査期間との関係は，前述した“群”の増重倍率と略々同様な傾向を示しているが，群に於いては，期間の推移と共に倍率が減少するのに対して，個体に於いては，第I期，A群，0.51，B群，0.77，第II期，A群，0.52，B群，0.78で，第I期よりも第II期の方が高率を示す。これは減耗率が第II期に於いて他の期間よりも顕著に高率を示し，且，環境の変化に比較的抵抗性の小さい小型魚が整理されたことに原因している。

第2実験　種苗の大きさの変異度が生産量に及ぼす影響

実験結果は第5表に示す通りである。この表から増重倍率及び餌料係数を求めた(第6表)。

各期間中の増重倍率は1，2の例外を除いて，A群よりもB群，a群よりもb群の方が大きく，全実験期間を通じての増重倍率は，A群0.17に対してB群0.56，a群0.94に対してb群1.75で少異の大きい群が小さい群よりも，又，若年魚（a群）の方が高年魚（A群）よりも高率を示した。増重倍率と飼育日数との関係は，第1実験の場合と同じく，日数の増加に伴つて倍率が減少する傾向が見られる。個体の増重量はA群0.29 g に対してa群2.47 g B群0.83 g，に対してb群2.36 g で若年魚の方が高年魚群よりも大きい。

餌料係数はA群よりもB群，a群よりもb群の方が小さく，全実験期間を通じてのその値は，A群12.0に対してB群5.0，a群4.3に対しb群2.9である。若年魚と高年魚とを比較すれば，前者の方が係数値は小さい。

Table 5. Results of experiment 2.

Group	Date	At time of fishing		Average weight(g)	Increase of weight(g)	No. of decreased	Amount of food(g)	Feeding period (days)
		Weight(g)	Number					
A	Apr. 30	167.6	15	11.17	20.1	0	51.8	12
	May 15	170.5	15	11.37	2.9	0	78.1	13
	May 30	165.0	15	11.00	−5.5	0	76.8	13
	June 14	171.9	15	11.46	6.9	0	86.0	13
	Total	171.9	15	—	24.4	0	292.7	51
B	Apr. 30	144.0	42	4.62	47.1	0	64.7	12
	May 15	217.5	42	5.18	23.5	0	112.4	13
	May 30	223.2	42	5.31	5.7	0	114.1	13
	June 14	228.8	42	5.45	5.6	0	118.1	13
	Total	228.8	42	—	81.9	0	409.3	51
a	Apr. 30	82.5	15	5.50	20.9	0	41.8	12
	May 15	90.1	15	6.00	7.6	0	74.2	13
	May 30	108.2	15	7.21	18.1	0	71.9	13
	June 14	119.5	15	7.97	11.3	0	62.2	13
	Total	119.5	15	—	57.9	0	250.1	51
b	Apr. 30	94.2	34	2.77	32.7	0	42.5	12
	May 15	114.0	34	3.35	19.8	0	83.9	13
	May 30	136.6	34	4.02	22.6	0	100.7	13
	June 14	169.4	33	5.13	32.8	1	85.5	13
	Total	169.4	33	—	107.9	1	312.6	51

Table 6. Showing the weight-multiplication rate and food quotient in each group.

Date	Weight-multiplication rate (W)				Food quotient (F)			
	A Gr.	B Gr.	a Gr.	b Gr.	A Gr.	B Gr.	a Gr.	b Gr.
Apr. 30	0.14	0.32	0.34	0.53	2.6	1.4	2.0	1.3
May 15	0.02	0.12	0.09	0.21	27.0	4.8	9.8	4.2
May 30	−0.03	0.03	0.20	0.20	—	20.0	4.0	4.5
June 14	0.04	0.03	0.10	0.24	12.4	21.1	5.5	2.6
From Apr. 16 to June 14 (60 days)	0.17	0.56	0.94	1.75	12.0	5.0	4.3	2.9

尾数の減耗はb群に1尾を生じたのみで，本実験結果から各群の比較を行うことは不可能である。

各群の体長及び体重の変異度を実験開始期と終了期に就いて比較すれば，開始期に変異度の小さいA群及びa群は，両期間に於いて顕著な差異を認め難いが，変異度の大きいa群及びb群は，何れも開始期より終了期の方が著しく小さい値を示している（第2，第7表）。

Table 7. Showing the body length and body weight at time of fishing.

Group	Body length			Body weight		
	Mean value	Standard deviation	Variant coefficient	Mean value	Standard deviation	Variant coefficient
A	11.35±0.13	0.75±0.09	6.59±0.81	11.51±0.39	2.26±0.28	19.65±2.52
B	8.65±0.15	1.41±0.10	16.35±1.23	5.46±0.32	3.03±0.22	55.45±5.18
a	9.91±0.11	0.61±0.08	6.19±0.76	8.02±0.32	1.85±0.23	23.09±2.99
b	8.24±0.12	1.00±0.08	12.09±1.01	4.67±0.28	2.42±0.20	51.67±5.32

考　　察

第1実験に於いて増重倍率は，種苗の大きさの小さい群の方が大きい群よりも高率を示した。これは生物の成長過程上からすれば当然のことで，飼育日数の増加に伴つて増重倍率の低下が認められ，又，第2実験の3才魚のA群と2才魚のa群とを増重倍率に就いて比較するに，後者の方が前者よりも遙かに大きいことは，以上の事実を証明している。

減耗率に於いて，大型魚よりも小型魚の方が高率を示したが，この原因は小型魚程環境並びに疾病に対する抵抗力が弱いことに依るものであろう。

餌料係数は第IV期に於いて，A群がB群よりも顕著に大きな値を示したが，この原因は，餌料の効率が，水温の低下により，魚の大きさで相異するのか，又はA群の第III期に性別が不明であつたものが，第IV期には明確に判別されたことよりして，栄養が生殖腺の発達の為に吸収されたとも考えられる。

第2実験に於いて，増重倍率は，種苗の大きさの変異度が大きいB群及びb群が，変異度の小さいA群及びa群よりも夫々高率を示した。この原因はA群及びa群と大型魚のようになるが，B群及びb群は大型魚と小型魚とが略々等量に混入されており，前述したように小型魚の成長率が，大型魚のそれに優る為に，かかる結果を生じたものと思われ，種苗の大きさの変異度の大きい群が，実験終了期に於いて変異の幅を大きく縮少していることは，小型魚が大きく成長し，大型魚に接近したことを示すものである。従つて，ドジョウに於いては，種苗の大きさの変異度は，生産量に影響を及ぼさないということが出来る。第III期に於けるA群の増重倍率は，負の値を示したが，この原因は産卵を行つた為と考えられる。何故なれば，同池には多数の稚魚が発見され，且，雌魚の体側に，産卵行為の際に生ずる白い摺傷が認められたことで明白である。

餌料係数は，変異度の大きい群が，小さい値を示したが，これは小型魚の方が大型魚よりも，餌料の効率が高いことに依るものと思われ，3才魚のA群よりも2才魚のa群の方が餌料係数の値が小さいことは，以上の事実を裏付けている。

本実験結果は，松井[2)3)]のウナギで行つた実験結果と大いに相違する。即ちウナギでは，魚体の大きい群が小さい群の成長を阻害して，大きい群が成長する為に，変異度が更に増大し，種苗の大きさの変異度の大きい群の方が，小さい群に比較して，増重倍率は小さく，餌料係数及び減耗率は大きくなるが，ドジョウでは，かかる事実は認められない。更に同氏は，シラスウナギを同一条件，同一方法のもとで138日間飼育した結果，体長の変異度は，A群，15.9%，B群，15.0%，C群，9.8% を示し顕著な成長量の変異を認めた。然し筆者等がドジョウで行つた実験[1)]では，体長の変異度は小さく，且，飼育日数の増加に伴つて大きい変化を示さな

かつた。即ち '54年6月に人工孵化させ，満3ケ年飼育した結果によれば，体長の変異度は，'54年8月2日，3.93±0.5(性別不明)，'55年7月28日，雌魚，3.89±0.06，雄魚，4.21±0.08 '56年8月11日，雌魚，3.85±0.06，雄魚，2.60±0.05，'57年4月11日，雌魚，3.90±0.06，雄魚，2.03±0.05である。これ等の原因は，ドジョウでは魚体の大きい個体が，魚体の小さい個体に対して，摂餌上，競合することなく，又，友喰いが行われない結果によるものと考える。

摘　　要

1）増重倍率は，大型魚よりも小型魚の方が大きい。
2）減耗率は，大型魚よりも小型魚の方が大きい。
3）餌料係数は，高年魚よりも若年魚の方が小さい。
4）種苗の大きさの変異度は，生産量に影響を及ぼさない。

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ドジョウの増殖に関する研究—II

放養密度が生産量に及ぼす影響※

久保田善二郎・松井　魁・白羽根元二

Studies on the Reproduction of the Loach, *Misgurnus anguillicaudatus* (CANTOR) II
On the Influence of the Loach Population Density upon the Productivity of Pond

By

Zenziro KUBOTA, Isao MATSUI and Genzi SHIRAHANE

We made the experiments of the loach on the relations of population density to weight-multiplication rate (W), decreasing rate (N) and food quotient (F).

The results are as follows:

1) The larger the population density is, the smaller the weight-multiplication rate and individual body weight are. On the contrary, the decreasing rate and food coefficient become higher.

2) The relation between population density (X) per 3.31 sq. m (tsubo) and weight-multiplication rate (W) is:

$$W = 33.817X^{-1.0042}$$

3) The relation between population density (X) and body weight (Y) at the close of the experiments is:

$$Y = 43.763X^{-0.5879}$$

4) The relation between population density (X) and average weight of one loach (Y′) is:

$$Y' = 1.790X^{-0.4707}$$

5) The relation between population density (X) and food quotient (F) is:

$$F = 0.058X - 2.354$$

6) The relation between population density (X) and decreasing rate (N) is:

$$N = 0.063X - 2.209$$

緒　　言

PEARL と PARKER (1922)[6][7] が Drosophila に豊富な餌料と充分な空気を与えた条件下に於いても，一定容積中にあつては，密度の増加に伴つて蕃殖率が減少し，且，平均寿命が短

※ 水産講習所研究業績 第240号，1957年7月25日 受理

縮することを報告して以来，密度効果に就いては，種々の動物に於いて研究が行われて来た。その中，魚類では WILLER と SCHNIGEWBERG (1927) はカワマスの放養密度と斃死率及び成長との関係を明らかにし，川尻 (1928)[1] はベニマスに就いて同様な実験を行い，密度の大きい方が減耗少なく，体重は軽く，密度の多少は全体重から見た増重率には影響の少ないことを明らかにした。寺尾・田中 (1928)[10] はメダカの産卵に及ぼす群居密度の影響に就いて研究し，群居密度 (X) と蕃殖 (Y) との関係は，同氏等がタマジンコで確立した実験式 $Y=ax^b$ で現わされるとした。川尻・畑・村井 (1930)[2] は，マスに就いて，放養密度の増大は，産卵数に対して無関係であるが，孵化率を低下させ，増肉率は少数群が多数群よりも効率が勝り，放養密度と魚の個体の成長及び孵化率との関係は，寺尾・田中がタマミジンコで示した関係式で表わされるとした。川尻 (1949)[4] は，ヒメダカに就いて群居密度の増大は，産卵数及び孵化率を減少させる傾向があることを，SWINGLE と SMITH (1950) は，池に放養する尾数と成長度の良否との関係を数種の魚に就いて示した。松井 (1952)[5] はウナギに就いて，放養密度の増大は増重倍率を低下させ，餌料係数及び減耗率を大きくし，放養密度が増重率に及ぼす限界点は坪当り100～150匁で，寧ろ100匁に偏するとした。吉原 (1952)[11] は，コイの成長に対する池の面積と放養密度の影響に就いて，夏季の増加は，近似的に直線で表わされ，その程度は密度が小さい程，密度が同じときは，尾数の少ない程夫々良好で，面積の影響は，これに比すると二次的に作用するとした。

以上の供試魚と習性上異つた生態を有するドジョウに就いて，同様の実験を試み，本魚の生産機構の基礎研究を行つた結果を報告する。

材料及び方法

供試魚は，実験A '54年6月から7月，実験Bでは '56年5月から7月に亘つて，下関市吉見町永田川及びそれに附帯する溝で採捕した稚魚及び同河川産の親魚から川村の方法で人工採苗した稚魚を使用した。

使用した実験池は，コンクリート製で，長さ190.5cm，幅92cm，底部は排水口に向つて4cm傾斜し，その排水口に隣接して直径35cm，深さ6cmの魚溜りを有する水産講習所の実験池を，実験Aでは4面，実験Bでは5面を夫々使用した。これ等の各池は，ドジョウの棲息環境に類似させるために，底部に泥土を5～10cmの厚さに敷き，水深は約30cmに保つて，換水は取揚時にのみ水道水で行いその他の時期は完全止水とした。

実験期間は，実験Aでは '54年8月6日から11月13日迄の99日間，又，実験Bでは '56年7月31日から10月18日迄の80日間である。而してこれ等の期間を実験Aでは5期，実験Bは4期に夫々区分して調査を行つた。

実験方法は，実験Aでは種苗を坪当り60g，120g，180gを，実験Bでは同様に60g，120g，180g，300gを各池に放養し，20日毎に取揚げて測定を行うと共に，増重した量を除去して密度を補正した。対照群は，実験Aでは坪当り30g，実験Bでは49.6gを夫々放養し，実験群と同時期に取揚げて調査し，密度の補正は行わないで，その儘，再放養した。

投与餌料は，蚕蛹と米糠とを乾燥重量比2：1の割合に混じて煮沸したものを，練り固めて磁製皿に入れ，実験Aでは，その皿を直接池底に設置したが，この方法では魚が摂餌する際に，餌料が皿の外部に散乱し，正確な摂餌量を求めることが出来ないので，実験Bでは，その皿は池中に予め用意された直径23.5cm，深さ8.5cmの洗面器の底部に安置した。餌料は乾燥餌料に

して，放養魚体重量の1/10量を1日1回，午前中に投与し，その残存餌料は，乾燥器で水分を除去して後，秤量し，摂餌量を求めた。

増重倍率（W），減耗率（N），餌料係数（F）は次式に依つて求めた。即ち放養時の重量をw_0，尾数をn_0，収納時の重量をw_1，尾数をn_1，飼育期間中の総投餌量をfで表わすと，次の通りである。

$$W=\frac{w_1-w_0}{w_0},\qquad N=\frac{100(n_0-n_1)}{n_0},\qquad F=\frac{f}{w_1-w_0}$$

飼育期間中の週平均水温は，実験A，第1図，実験B，第2図に夫々示した。即ち水温は，実験Aでは，実験開始期30.7°C，同終了期14.1°Cで，両期間の温度差は16.6°Cで週平均1.2°C宛降下し，その低下の傾向は9月13日迄は緩慢であるが，それ以後では，若干度合を増す。又，実験Bでは，開始期，29.7°C，終了期，19.5°Cで，両期間の温度差は，10.2°C，週平均1°C宛低下している。この低下の傾向は略々一定の割合で行われているが，9月6日前後に若干の温度上昇が認められる。実験期間中の平均水温は実験A，22.9°C，実験B，24.8°Cで前者の方が後者よりも1.9°C低温である。これは飼育期間が実験Bよりも実験Aの方が長期に亘つた為で，両実験の水温を同一時期（8月9日～10月14日）に就いて比較すれば，平均水温は実験A，24.9°C，実験B，24.3°Cで略々同一である。

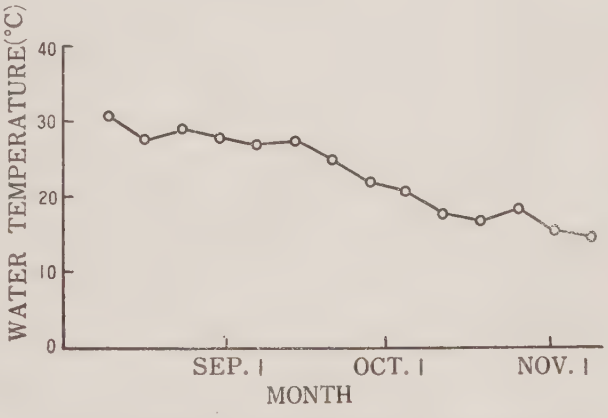

Fig. 1. Variation of water temperature during the period of experiment A.

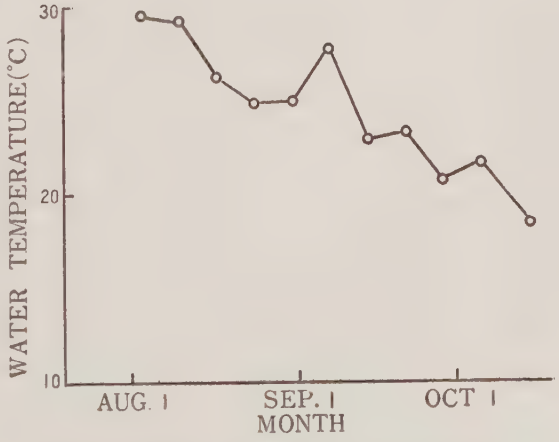

Fig. 2. Variation of water temperature during the period of experiment B.

実　験　結　果

測定結果は，実験A，第1表，実験B，第2表に夫々示した。

この表から増重倍率（W），餌料係数（F），減耗率（N）及び1尾の平均体重を求めた（第3，第4表）。但し実験Aの餌料係数は，前述した様に，投餌方法に缺陥があり，摂餌量の正確性を缺く故省略した。

実験Aの結果

増重倍率は，第I，第II期では，各群間に於いて顕著な差異が認められ，60g群が最大，

Table 1. Results of experiment A.

Periods	Amount of cultured loaches per tsubo (g)	Amount of cultured		Catch		Individual body weight (g)		Increasement of body weight (g)	Amount of food (g) (days for feeding)
		Weight (g)	No.	Weight (g)	No.	Releasing time	Catch time		
I	60.0	30.0	46	67.0	43	0.65	1.56	37.0	51 (17)
(Aug. 6	120.0	60.0	107	106.7	95	0.56	1.12	46.7	102 (17)
~	180.0	90.0	164	145.6	147	0.55	0.99	55.6	153 (17)
Aug.25)	30.0	15.0	17	34.5	17	0.88	2.03	19.5	26 (17)
II	60.0	30.0	19	42.5	17	1.58	2.50	12.5	48 (16)
(Aug.26	120.0	60.0	53	75.2	47	1.13	1.60	15.2	96 (16)
~	180.0	90.0*	94	109.5	83	0.96	1.32	19.9	144 (16)
Sep.14)	69.0	34.5	17	40.6	17	2.03	2.39	6.1	54 (16)
III	60.0	30.7	12	37.4	11	2.50	3.40	7.4	36 (12)
(Sep.15	120.0	60.0	37	79.0	36	1.62	2.19	19.0	72 (12)
~	180.0	90.0	68	86.6	61	1.32	1.42	−3.4	108 (12)
Oct. 4)	81.2	40.6	17	48.8	17	2.39	2.87	8.2	49 (12)
IV	60.0	30.0	9	34.0	9	3.33	3.75	4.0	45 (15)
(Oct. 5	120.0	60.0	27	68.7	26	2.22	2.64	8.7	90 (15)
~	180.0	90.0	64	106.8	59	1.41	1.81	16.8	135 (15)
Oct.24)	97.6	48.8	17	52.5	17	2.81	3.09	3.7	74 (15)
V	60.0	30.0	8	29.8	8	3.75	3.73	−0.2	36 (12)
(Oct.25	120.0	60.0	23	61.5	23	2.61	2.67	1.5	72 (12)
~	180.0	90.0	50	92.0	50	1.80	1.84	2.0	108 (12)
Nov.13)	105.0	52.5	17	52.7	17	3.09	3.10	0.2	64 (12)

Remarks : 1 tsubo = 3.306m²

Table 2. Results of experiment B.

Periods	Amount of cultured loaches per tsubo (g)	Amount of cultured		Catch		Individual body weight (g)		Increasement of body weight (g)	Amount of food (g) (days for feeding)
		Weight (g)	No.	Weight (g)	No.	Releasing time	Catch time		
I (July 31 ~ Aug. 19)	60.0	30.0	54	61.4	54	0.56	1.14	31.4	27.8 (15)
	120.0	60.0	99	70.3	80	0.61	0.88	10.3	86.0 (15)
	180.0	90.0	147	139.0	137	0.61	1.01	49.0	124.0 (15)
	300.0	150.0	268	196.5	234	0.56	0.84	46.5	183.2 (15)
	49.6	24.8	79	42.0	76	0.31	0.55	17.2	26.4 (15)
II (Aug. 20 ~ Sep. 8)	60.0	30.0	26	53.0	26	1.38	2.04	23.0	37.0 (18)
	120.0	60.0	67	90.0	67	0.90	1.34	30.0	78.5 (18)
	180.0	90.0	84	106.0	71	1.07	1.49	16.0	104.9 (18)
	300.0	150.0	185	149.0	143	0.81	1.04	−1.0	188.2 (18)
	84.0	42.0	76	60.0	61	0.55	0.98	18.0	60.5 (18)
III (Sep. 9 ~ Sep. 28)	60.0	30.0	14	38.0	14	2.14	2.72	8.0	16.6 (17)
	120.0	60.0	42	77.2	42	1.43	1.84	17.2	49.8 (17)
	180.0	90.0	58	95.0	50	1.55	1.90	5.0	89.6 (17)
	300.0	150.0	144	142.0	107	1.04	1.33	−8.0	166.8 (17)
	120.0	60.0	61	72.7	59	0.98	1.23	12.7	62.4 (17)
IV (Sep. 29 ~ Oct. 18)	60.0	30.0	10	40.5	10	3.00	4.05	10.5	8.6 (16)
	120.0	60.0	29	77.0	29	2.07	2.66	17.0	42.2 (16)
	180.0	90.0	46	102.2	46	1.96	2.22	12.2	74.3 (16)
	300.0	150.0	114	166.0	104	1.32	1.60	16.0	154.3 (16)
	145.4	72.7	59	81.3	55	1.23	1.48	8.6	70.4 (16)

Table 3. Weight-multiplication rate, decreasing rate and average body weight per loach in experiment A.

Population density (g)	Items \ Period	I	II	III	IV	V	Average
60	W	1.23	0.42	0.25	0.13	0.01	0.41
	N	6.5	5.3	8.3	0.00	0.00	4.0
	Average b. w. (g)	1.56	2.50	3.40	3.78	3.73	2.99
120	W	0.78	0.25	0.32	0.15	0.03	0.30
	N	11.2	11.3	2.7	3.7	0.00	5.8
	Average b. w. (g)	1.12	1.60	2.19	2.64	2.67	2.04
180	W	0.62	0.22	−0.04	0.19	0.02	0.20
	N	10.3	11.7	10.3	7.8	0.00	7.8
	Average b. w. (g)	0.99	1.32	1.42	1.81	1.84	1.48
Unadjusted density	W	1.30	0.18	0.20	0.08	0.00	0.35
	N	0.00	0.00	0.00	0.00	0.00	0.00
	Average b. w. (g)	2.03	2.39	2.87	3.09	3.10	2.69

Remarks : W, weight-multiplication rate. N, decreasing rate.

Table 4. Weight-multiplication rate, food quotient, decreasing rate and average body weight per loach in experiment B.

Population density (g)	Items \ Period	I	II	III	IV	Average
60	W	1.05	0.77	0.27	0.35	0.61
	F	0.89	1.61	2.08	0.82	1.35
	N	0.0	0.0	0.0	0.0	0.0
	Average b. w. (g)	1.14	2.04	2.14	4.05	2.34
120	W	0.17	0.50	0.29	0.28	0.31
	F	8.35	2.62	2.89	2.48	4.09
	N	19.2	0.0	0.0	0.0	4.8
	Average b. w. (g)	0.88	1.34	1.84	2.66	1.68
180	W	0.54	0.18	0.06	0.14	0.23
	F	2.54	6.55	17.92	6.09	8.28
	N	6.8	15.5	13.8	0.0	9.0
	Average b. w. (g)	1.01	1.49	1.90	2.22	1.66
300	W	0.31	−0.07	−0.05	0.11	0.08
	F	3.94	—	—	9.64	—
	N	12.7	22.7	25.7	8.8	17.5
	Average b. w. (g)	0.84	1.04	1.33	1.60	1.20
Unadjusted density	W	0.69	0.43	0.21	0.12	0.36
	F	1.53	3.30	4.91	8.18	4.48
	N	3.8	19.7	3.3	6.8	8.4
	Average b. w. (g)	0.55	0.98	1.23	1.48	1.06

Remarks : W, weight-multiplication rate. F, food quotient. N, decreasing rate.

180 g が最小で，密度が大きい群程小，小さい群程大である。第 III 期以後では，各群間の差異は小さくなり，実験終了期の第V期では殆んど認められない。密度を補正しなかつた対照群の増重倍率は，第 I 期に於いて，他の何れの群よりも大きいが，第 II，第IV，第V期では最も小さく，第 III 期では，60 g 及び 120 g の両群よりも小さく，180群よりも大きい値を大々示した。各群の増重倍率は，実験初期に於いて大きく，飼育日数の増加に伴つて減少する傾向がある。

個体の平均体重は，期間の推移に伴つて，群間の差異が増大し，実験群の中では，各期間共，60 g が最大，180 g 群が最小で，放養密度が大きい群程小さい。対照群の平均体重は，第 I 期では，各群中，最大であるが，放養密度が 81 g に達した第 II 期には，60 群と略々一致し，第 III 期以後では60 g 群よりも小さく，120群よりも大である。

減耗率は，第 I 期の120 g 群と180 g 群，第 II 期の60 g 群と120 g 群の様な例外もあるが，一般に，密度の大きい群程大，小さい群程小である。対照群の減耗は皆無であつた。

実験 B の結果

増重倍率は，各時期に於いて相当な差異がある。即ち，第 I 期では，120 g 群を除いて，各群共，各期間の中で最大値を示し，それ以後第 III 期にかけて急激に減少し，第IV期では，第 III 期と比較して，若干大きいか，又は同程度の値を示し，全般的には，実験 A の場合と同様に，飼育日数の増加に伴つて，増重倍率が減少する傾向がある。放養密度と増重倍率との関係は，第 I 期に於ける 120 g 群の様な例外もあるが，各時期共，密度の小さい群程大きく，大きい群程小さい値を示す。第 I 期に於ける120 g 群が例外的に最小値を示したのは，他発的事故により，全長約10cmのフナが 3 尾混入していた事によるもので，これ等を除去した第 II 期では，60 g 群に次ぐ大きい値を示した。対照群の増重倍率は，第 I 期に於いて60 g 群より小さく他の 3 群よりは大きいが，それ以後漸時減少し，第 II，第 III 期では60 g 及び120 g 群よりも小，180 g 及び300 g 群よりも大で，第V期では群間中で最小の値を示した。

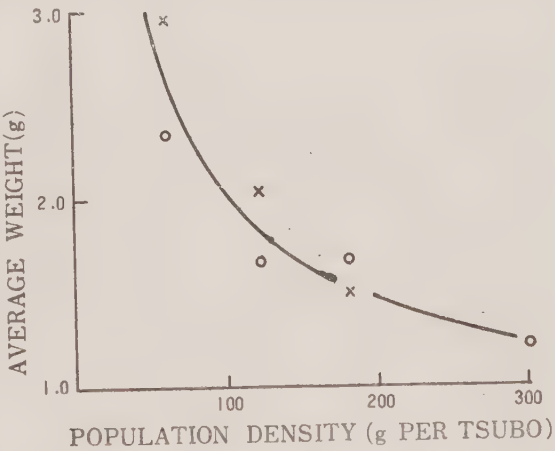

Fig. 3. Relation between the population density and the weight-multiplication rate.
× ; exp. A :　; exp. B.

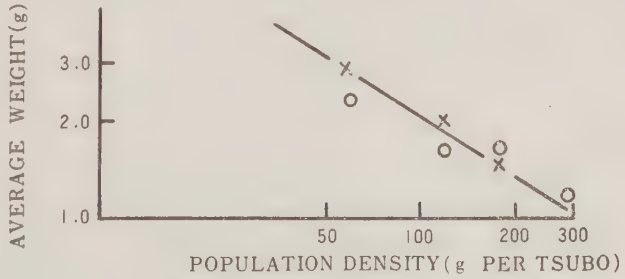

Fig. 4. Relation between the population density and the weight-multiplication rate.
× ; exp. A　: ○ ; exp. B.

個体の平均体重は，第 III 期迄 60 g 群が最大，続いて 180 g 群，120 g 群，300 g 群の順位で

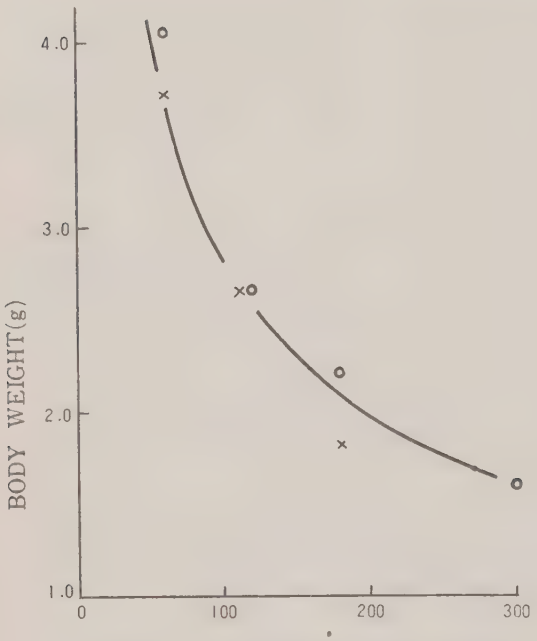

Fig. 5. Relation between the population density and the body weight at the close of experiment.
× ; exp. A　: ○ ; exp. B.

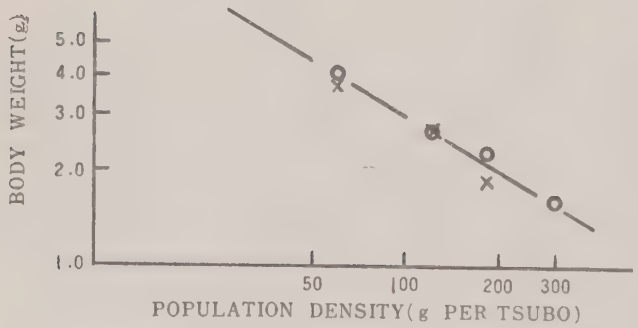

Fig. 6. Relation between the population density and the boby weight at the close of experiment.
× ; exp. A　: ○ ; exp. B.

あるが，第V期には120g群が180g群の上位になり，密度が小さい群程大，大きい群程小である。対照群の平均体重は，全期間を通じて各群よりも小さい。

減耗率は，1.2の例外を除いて，放養密度の大きい群程大，密度が小さい群程小で，各期間の減耗率の平均値は60g群，0%，120g群，4.8%，180g群，9.0%，300g群，17.5%である。

餌料係数は，第I期の120g群のみは例外であるが，各期間共，放養密度の小さい群程小さく，大きい群程大きい値を示している。この事実は，対照群にも適合し，飼育日数の増加による放養密度の増大に伴つて，係数値も大きくなる

実験A及び実験Bの総括

実験A及びBの放養密度（X）と各期の増重倍率の平均値（W）との関係は，曲線で示され（第3図），更に両者の対数をとれば直線となり（第4図），$W=aX^b$ の実験式が成立し，係数a及びbの値を求めると

$$W=33.817X^{-1.0042}$$

となる。

同様にして，放養密度（X）と実験終了時の体重（Y）との関係は

$$Y=43.763X^{-0.5879}$$

となり（第5，第6図），放養密度（X）と個体の平均体重（Y'）との関係は

$$Y'=1.790X^{-0.4707}$$

の関係式が夫々成立する（第7，第8図）。

放養密度と餌料係数及び減耗率との関係は，夫々直線となり（第9，第10図），従つて両者の関係は，$Y=aX$ の式で表される。

餌料係数をF，減耗率をN，放養密度をXとし，夫々の係数aを求めると次式が成立する。

即ち　$F=0.058X-2.354$

$N=0.063X-2.209$　で表わされる。

考　　察

実験AとBとを，夫々に共通した放養密度群，即ち60g，120g，180gの各群に就いて，実験成績を比較すれば，増重倍率は，60g群に於いて実験A，0.41に対して，実験B，0.61，同様にして120g群，0.30に対して0.31，180g，0.20に対して0.23で，実験Bの方が良好なる成績を示し，減耗率では60g群，4.0に対して0.0，120g群，5.8に対して4.8，180g群，7.8に対して，9.0，そして平均体重では，60g群，2.99に対して2.34，120g群，2.04に対して1.68，180g群，1.48に対して1.66で，両実験間の値は若干相異する。この原因は実験年度を異にする為の気象，増殖技術，種苗等を異にする為と考えられる。増重倍率は飼育日数の増加に伴つて減少する傾向があるが，これは主として前報告で述べた成長段階に於ける成長率の差異

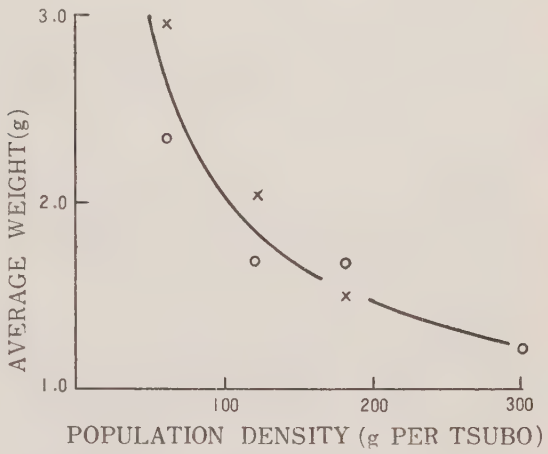

Fig. 7. Relation between the population density and the average body weight.
× ; exp. A　: ○ ; exp. B.

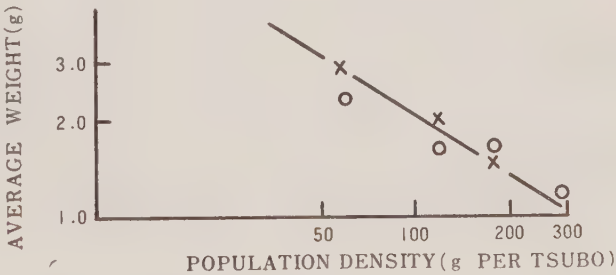

Fig. 8. Relation between the population density and the average body weight.
× ; exp. A　: ○ ; exp. B.

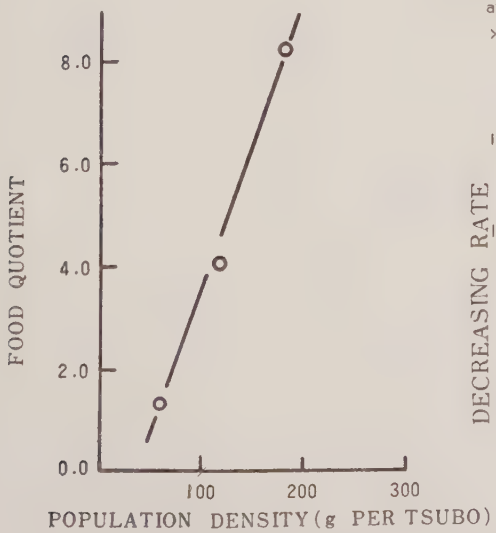

Fig. 9. Relation between the population density and the food quotient.

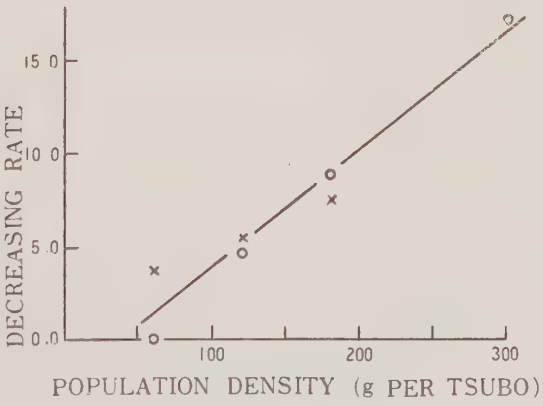

Fig. 10. Relation between the population density and the decreasing rate.
× ; exp. A　: ○ ; exp. B.

に基づくものであろう。

対照群は，同程度の密度を有する実験群と比較して，両実験共に，増重倍率は劣る成績を示したが，この原因は，調査時に於ける操作上の不備によるものか，又は密度を補正することが刺戟となつて，対照群よりも実験群の成長が促進されたとも考えられるが，更に検討を要する点であろう。

実験Bの平均体重に於いて，対照群は全期間を通じて，各群中，最小の値を示したが，これは，放養時の体重が実験群よりも0.25～0.30g軽く，前報告で述べた様に，同一密度に放養した場合，個体の増重量は，体重の重い群程大きいことによるものであろう。

実験Bに於ける60g群の餌料係数は，第I及び第IV期で，夫々1以下の値を示し，摂餌量よりも増肉量の方が大きいことを現わしている。この事実は，田中(1948)[8]が報告した如く，魚が池中に発生した天然餌料を補食したことを意味する。而してこれ等の餌料生物も又，密度の影響を受けて蕃殖すると思われる故，同一条件である各池の天然餌料の量は，略々一定とみなされ，従つて養魚の密度の小さい群程，体重当りのその量は大となり，これ等の補食量の多少は，魚の増重及び餌料係数に，かなりの影響を与えることが考えられる。

川尻 (1928)[1]，川尻・畑・村井 (1930)[2]，川尻・畑 (1935)[3] はベニマス及びカワマスに於いて，放養密度が大きい方が減耗少なく，平均体重軽く，且，生産量に関して影響が少いとした。又松井 (1952)[5] は，ウナギに於いて密度が大きい程，増重倍率，平均体重は小さく，餌料係数及び減耗率は大きいことを報告した。これ等の報告と本実験結果とを比較すれば，前者の各研究結果とは平均体重に就いてのみ一致し，減耗及び生産量に関しては，全く相反し，又，後者の結果とは，総の点に関して一致する。この原因は，松井 (1952)[5] が指摘した様に，飼育方法がマス類とドジョウ及びウナギとでは異り，前者は流水性に対して後者は止水性であつて，養成方法の差異に基いて，放養密度の影響が異なるためと考えられる。

摘　　要

1）放養密度が大きい程，増重倍率，実験終了時の体重，平均体重は夫々小さく，餌料係数及び減耗率の値は大きい。

2）放養密度（X）と増重倍率（W）との関係は

$$W=33.817X^{-1.0042}$$

の実験式で表わされる。

3）放養密度（X）と実験終了時の体重（Y）との関係は

$$Y=43.763X^{-0.5879}$$

の式で表わされる。

4）放養密度（X）と平均体重（Y′）との関係は

$$Y'=1.790X^{-0.4707}$$

の式で表わされる。

5）放養密度（X）と餌料係数（F）との関係は

$$F=0.058X-2.354$$

の式で表わされる。

6）放養密度（X）と減耗率（N）との関係は

$$N=0.063X-2.209$$

の式で表わされる。

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赤道海域で採集したカツオの仔魚※

石山礼蔵・岡田啓介

Postlarval Form of the Skipjack (*Katsuwonus pelamis*) from the Phoenix Islands

By

Reizo Ishiyama and Keisuke Okada

Several young fishes were caught near the Phoenix Islands, central Pacific. The characteristic features of the young, measuring from 5mm to 8mm, agree well with those of the postlarvae of the skipjack. (Fig. 1 A, B), which have been described by Wade (1953) and others.

本所の練習船俊鶻丸は昭和28年（1953）1月上旬より2ケ月間に亘り，ハワイ及び赤道海域のカツオ・マグロ漁場調査の実習航海を行つた。その際，Phoenix 群島近海に於いて可なり優秀な漁場を発見し，同時に得た稚魚類を調べた結果，カツオの後期仔魚に同定されるものが見出されたのでここに報告する。

従来，カツオ・マグロ類の稚幼魚に就いては多数の研究が発表され，特に印度太平洋海域のものでは，Mead(1951)，Scheafer and Marr(1948)，Shimada (1951) 及び Wade (1951) 等の報告がある。就中，Wade のフイリツピン近海で採集した多数の稚仔魚の詳細な研究は最も優れたものである。

カツオ・マグロ類の資源研究が益々重要な課題となりつつある現在，吾々の僅かな記録も参考資料として幾分かの価値があろう。

材料その他

標本はすべて大型稚魚ネツト（直径2m）で夜間採集し，直ちにホルマリン液（5～7%）に保存した。

採集位置は3°5′S，169°9′ Wで，Phoenix 群島の西南海域に当る。

採集当日（昭和28年2月23日）の海況は次の如くであつた：水温(表面)，27.8°C；透明度，28m；プランクトン沈澱量，7.1cc/m³。

カツオの稚魚として同定された標本は全部で 11尾，それ等の測定値は表示した様に，全長 5.1～8.0mm である。これらの中，数尾は透明標本として詳しく調べた。

魚種の査定には特に Wade の研究を参照した。調べた標本はすべて本所の所蔵として保存されている。

※水産講習所研究業績 第241号，1957年7月25日 受理

Table 1. Measurements of postlarval *Katsuwonus pelamis*, in mm.

No.	Total length	Body hight	Head length	Snout length	Eye diameter	Snout to anus
1	5.9	2.0	2.5	1.1	1.0	3.2
2	6.6	2.5	2.7	1.5	1.2	3.8
3	7.0	2.2	3.0	1.2	1.5	4.0
4	5.8	2.0	2.2	1.2	1.0	3.0
5	5.5	2.0	2.3	1.3	1.0	2.7
6	5.3	1.9	2.1	1.3	1.0	3.0
7	5.1	1.9	2.0	1.2	0.9	3.0
8	5.2	1.9	2.0	1.0	0.9	2.6
9	5.0	1.6	2.2	0.9	0.8	2.1
10	7.0	2.3	2.9	1.2	1.5	4.1
11	8.0	2.5	3.2	1.6	1.4	4.1

結　　果

1）全長 5.9mm：体の概形は魚類の幼期の形と特に異つておらず，体高は後頭部に於いて最大を示し，頭部は体の残部に比して不均合に大きい。頭長は全長に対して約35%を占め，体部は長くほつそりとしている。頭部軸は体軸に対して僅か下方へ曲つていて「へ」の字型を呈している。C. B Wade はこの状態を佝僂状といつている。

体高は頭部主鰓蓋骨附近に於いて最大を示し，腹腔附近で少し狭くなりそれ以後尾鰭に向つて極端に細くなつている。頭部は鋭角的に尖り，吻端より頭頂に至る迄は多少凝つた外廓である。口は大きくて頭部の先端に開き，且つ斜め上に向いている。上方より観察する吻は鋭角状に突出していて，左右の前顎骨の縫合が明らかに認められ，左右各々の側に3ケの突出した犬歯状の歯を認める。吻は長く突出しており，吻部は正三角形を呈し，頭部の約50%を占めている。吻の先端は瞳孔下顎水平延長線上にある。上顎先端は尖り，下顎先端はやや截形を呈している。上顎は下顎より僅かに突出している。上下両骨縫合部の後端は瞳孔後端垂直下に達している。各側の前上顎骨には小さくて細い犬歯状の歯が11ケあり，その中，前端部の歯は鈎状をしている。口蓋中央部下縁にも2ケの歯がある。下顎には9ケの犬歯状の歯を認め，上・下両顎を通じて歯は基部と先端部の2つに分かれている様に観察される。歯の並び方は不規則である。

肛門は体中央腹腔の後端部に開孔している。腹腔は大きくて角が円い正三角形状をなし，体の中心部を占めている。腹面よりの観察では腹腔は前方に向つて広く，後方に於いて狭くなつており，その中央稍前方に腹鰭がある。

眼は大きくて頭部の中心位置を占め，その直径は吻長よりも僅かに短く前方斜め下方に一欠刻を見る。瞳孔の大きさは眼径の½よりも小さい。鼻孔は眼の前方，吻の後部に楕円形をなして明らかに認められる。

脊椎骨は未だ発達していないので，魚体の中心に沿つて脊索が走り，その後端は細くて真直に延長している。尾下骨板の原鰭はすでに現われている。体側筋肉節は体側中央に於いては明瞭に認めることが出来るが，前部及び尾柄部に於いては不明瞭である。数へ得る体側筋肉数は38=5+33。

第1背鰭は脊椎骨の始部附近より発生し，第1，第2背鰭共に未だ膜状で連続しているが結締組織の鰭条えの変化が僅かに観察される。この鰭膜は尾鰭のそれと連絡している。

腹鰭は第1背鰭の始部と対掌の位置即ち，腹腔底の稍前方に膜鰭としてみられ，結締組織の変化がみられる。

胸鰭は団扇状で大きく，全体が膜状で，透明標本では識別し難いが上面より観察すると第1背鰭と腹鰭の中間より稍下方に位置する。

臀鰭は未だ発達せず肛門直後より膜鰭として存在し，第1，第2背鰭と同様結締組織の鰭条化が僅かに観察され，尾鰭の膜鰭と連絡している。

尾鰭は脊索端と発達途中の尾下骨板に依つて支えられた約12ケの鰭条が認められるが尾鰭の上葉及び下葉は殆んど膜鰭の状態である。脊索後端の上向部の背方には結締組織から骨髄化えの過程と思われる状態が認められる。胸鰭及び尾鰭はこの仔魚期に於ける游泳器官として重要な役割をなすものと思われる。

前鰓蓋骨の後端に沿つて7棘が発達している。この中，細くて長い2本の棘は前鰓蓋骨の中央の屈折部に在つて，上方の1棘は水平方向に延長している。次いで他の1棘は前棘の腹方で斜め下方に延びこの最も長い棘（上方より4番目）は腹鰭後端に達する。前鰓蓋骨垂直線に沿つて発生している別の2棘は細かくて鋭く尖る。その長さは一番長い棘の約1/4である。他の3棘は前鰓蓋骨後縁に沿つて存在し，腹方に進むに従い棘は漸次短かくなつている。以上前鰓蓋骨後縁の棘はいずれも後方に向つて延び，上部3棘は水平方向又は稍上方に向つて延びている。他の4棘はいずれも下方に向つて延びている。本仔魚を背面より観察すると棘の前鰓蓋骨後縁より突出した部分は体側壁と可成り相離れて外方に向い延長している。その角度は最大の長さを有する2棘が最も大きく，上下の棘になる程体側に対して並行に延びている。各棘共中央に隆起脈があつて各々の隆起脈の基部に向う延長は総てが1ケ所に集る様である。更に前鰓蓋骨の中央部を走る隆起縁には2ケの短い棘がある。

仔魚の喉部附近には鰓皮条があり後方に移るに従つて長くなつている。ホルマリン保存標本の体色は白い。

黒色色素は良く発達していて，眼球・吻端・項部・腹腔及び尾柄部の腹側縁と尾鰭中央に見られる。眼球背方の脳を覆つている膜には明瞭な黒色色素が在る。これを背面より観察すると26ケの色素が数えられ，その周囲には極く小さい黒色色素が存在する。背面より見ると脳を覆つている色素群は円形に散在し，頭部背面の広い部分を占めている。腹腔に於いてもその前部及び特に背面附近で小円形色素が多く見られ，体側に向うに従つて濃密となり黒色を呈している。その中にやや大きな黒色色素が散在する。尾柄部の腹縁に沿つて数え得る体側筋肉節の後方や後方から第4番目の筋節に楕円形の黒色色素が存在し，それより2節前に小黒色色素が存在している。尾柄中央脊索端下方に星状黒色色素がある。（Fig. 1 A）

2）全長　6.6mm：1）に記載したものと概形に於いては変化は認められないが細部に於いては多少進んでいると思われる。頭長の全長に対する割合は約40%と変化している。吻長の頭長に対する割合は40%となり1）に記載したものより吻長の占める割合が減少している。吻先端は瞳孔下端水平延長線よりも僅かに上方にある。口裂の角度は1）よりも斜めになつている。各側の前上顎骨には犬歯状の歯が12本あり，口蓋骨に2本見られ，下顎にも12本の歯を認める。歯の並びは両顎歯相対応して等間隔に並んでいる。鼻孔は齲状に縊れている。

肛門は体中央より稍前方に開口している。脊椎骨も1）と同様未発達であるが，尾下骨原基は既に発達している。体側筋節数は 39＝7＋32。

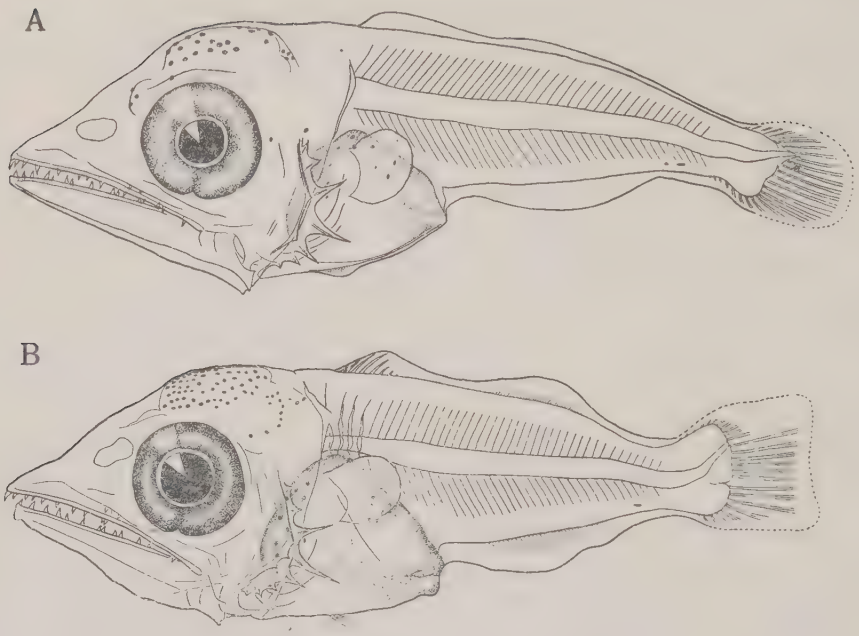

Fig. 1. Postlarvae of *Katsuwonus pelamis*. A, 5.9mm ; B, 7.0mm.

第1背鰭には発達した4本の鰭条が見られる。腹鰭はその大きさを増しており，明らかに3鰭条が認められるが位置は腹腔底中央へと移動している。胸鰭はその大きさを増している。尾鰭は良く発達し約20本が鰭条として数えられる。しかし，僅かに上・下葉に分かれる凹部が認められる。

前鰓蓋骨の後縁に沿つて発生している棘も大きさと鋭さを増している。前鰓蓋骨の中央部を走る隆起縁に沿つて3本の等間隔に並んだ短い棘がある。

黒色色素胞は頭部・眼の上方・脳を被つている膜には28ケ数えられ，又，尾柄部腹縁に沿つて在る色素も体側筋節の後方4番目に楕円形の色素1ケのみとなつている。尾柄中央の星状黒色色素は消えている

3）全長 7.0mm：1），2）に記載したものよりも更に進んだ時期のものである。体の概形は前記のものと良く似ているが魚体が幾分頑丈になつている。頭部が大きい事では変りはなく，頭長の全長に対する比は約30%に変化している。体軸に対する頭部軸は幾分直線的であつて前記1），2）の如く湾曲していない。上下両顎に於ける歯は鋭さを加え，数も増加して認められる。鼻孔は前後のくびれがはつきりとして，2分しようとしている。椎体は前方に於いて4，5ケ形成され神経棘が明らかに形成されている。体側筋肉節は39＝6＋33で1），2）に比較して肛門がだんだんと後方え移つて来ている。

腹鰭は4棘となり，その長さは前記載のものよりも長大である。臀鰭基底は半ば現われている。尾鰭は良く発達した尾下骨板と共に鰭条も良く発達している。前鰓蓋骨の端に沿つて8棘が発達し，2）よりも1棘増加し，前鰓蓋骨腹側後縁の端に小さな棘として発生している。

黒色色素は頭部背面及び腹腔の部分等に良く発達している。頭部背面の色素胞は2）よりも密に発生し，頭頂に行くに従つて多く分布している。その数は19ケ認められる。尾柄部腹縁に

見られる1ケの楕円形の色素には変化がない。(Fig. 1 B)

査　　定

以上述べた観察結果は主として Wade (1951) の記載及び図と比較した。Wade (1951) はフイリツピン海域に於けるカツオ・マグロ類似の仔魚に関する研究に於いて多数の仔魚標本の査定を行つているが，決定されたものは数種類のみであり仔魚同定の困難さを伺い知ることが出来る。筆者等は前記の標本がカツオの仔魚であると同定するに充分な条件を既発表の文献との比較対象及び検討することに依つて決定した。Wadeは仔魚査定に当つて，体の概形，口の大きさ及び位置，吻と肛門の位置，背鰭及び尾鰭の発達の程度，前鰓蓋骨後縁に沿つて見られる棘，吻端及び頭頂に分布する黒色色素胞等の要素をこれ等仔魚決定の条件としている。本研究に於いては以上の諸特徴を査定の基準とし，且つ，体側筋節数をも考慮して標本仔魚を査定する根拠とした。是等後期仔魚期の極めて明らかな特徴は頭部上方・尾柄部等の黒色色素胞及び前鰓蓋骨に沿つて見られる棘であるが，この中，棘は後に退化萎縮するものであることは疑いない。その結果 Wade が記載しているカツオの後期仔魚としての諸特徴と，この研究の標本仔魚のそれと一致している諸点をあげると

1）頭部は軀幹部に比較して大きい。即ち，頭部は全長に対して40%を占めていて，全体的に見て頭部が大きくてセムシ状を呈していること。

2）口は大きくて広く開き，上・下両顎骨縫合部の後端は瞳孔後端垂直下に達していること。

3）尾鰭鰭条数が略一致すること。

4）体高が高く，吻は長く尖り，吻長と眼径の比に於いて体長 5.0～6.1mm では吻長が大で，7.0mm以上では眼径が大きくなつている。

5）頭頂に存在する黒色色素胞の数及び分布状態からもキハダの仔魚と区別することが出来る。

6）尾柄部腹縁に黒色色素胞を1ケ有する。

標本　1)，2）及び 3）に於いては透明処理をした為に吻先端にある黒色色素胞を認めることが出来なかつたが，他のホルマリン保存標本に於いては明らかに認めることが出来る。又，下顎先端・週辺及び上顎先端にも認めることが出来る。更に Wade は記載していないが図に依つて体側筋節数を調べると 7.15mmの標本では39ケ有り，本標本仔魚 7.0mmの個体では 39ケで両者は一致している。

以上の比較考察の結果今回調べた後期仔魚はすべてカツオと同定することには間違いはないと思われる。しかし，本魚種の査定の根拠として眼・口・頭等の部分の大きさの比較に依らなければならないこと，その種として決定せられる可き脊椎骨数，背鰭・臀鰭鰭条数等の重要な特性もこれらの後期仔魚期では明らかに決めることが出来ないのみならず，これ等要素の仔魚に於ける種内変異の範囲も明らかにされていないので，普遍的要素でもつて同定し得ないこと，体の各部分の比等も勿論固定的なものでなく，特に仔魚に於いては変化をする為相当の範囲の変異を考えておかなければならない。故に，種の決定に於いてはこれらを満足させるものを選ばなければならない。

類似仔魚との区別

後期仔魚期に移つた時代，即ち，このような若い時代に於いては前述の如く，その種としての特徴がはつきりとしていないから標本の同定に当つては充分の注意を要する。カツオ仔魚

の場合は特にキハダ・スマの仔魚との識別が重要である。Wade が之等類似の2種の仔魚を図示及び記載している故に，筆者等の記載した標本と比較してその識別をした。

キハダ *Neothunnus macropterus* (T. et S.)

体側筋節数は記載に依ると 6.19mmで 36，6.7mmで38となつている。幼期 (5.5mm) は体表面に黒色色素のないこと及び，頭部は中庸の大きさで，口は頭部に比してカツオより大きくはないこと，吻先端部に黒色色素の分布を見ない。尾柄部腹縁に黒色色素のない等がカツオの仔魚と異る主な点で，これ等でもつて両者は区別出来る。

スマ *Euthynnus yaito* (KISHINOUYE)

6.5mm の標本において脊椎骨数は36である。頭部は比較的小さく，体表面の黒色色素は少く，故に頭部表面は色素にとぼしい。又，背鰭・尾鰭鰭条は早くから出現する。黒色色素群が尾柄部，背腹両縁に沿つて小さな斑をなし2～3ケ存在する。吻端には色素がない。

要　　約

昭和28年1～3月の俊鶻丸航海において，赤道海域 Phoenix 群島近海で数尾の仔魚を採集した。

仔魚の全長は5～8mmで，その外部形態，特に頭部の形状，歯系及び黒色色素の発生の状態等の特徴によつてカツオの仔魚に同定された。

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鯉の第一次産卵数と孕卵数との関係について※

松井　魁

The Number of Eggs discharged at its Primary Spawning in Relation to the Number of Ovarian Eggs in Carp.

By

Isao MATSUI

The number of eggs found in ovary of carp, namely, 190,000—700,000, is reduced to 15.4—51.9% by discharging 50,000—620,000 eggs at its primary spawning. The number of the eggs of the primary discharge (P) stands in such relation to the body weight (W) as given by the formula (1).

$$P=\frac{651,800}{1+e^{3.500-0.953W}} \quad \cdots\cdots (1)$$

The formula (2) describes the relation between the number of the ovarian eggs (O) and the body weight

$$O=735,300\left\{1-0.732^{-0.374(W-1)}\right\} \quad \cdots\cdots (2)$$

These formulae suggest that a female at least over 4kg in weight should be employed for successfully carrying artificial insemination.

緒　　言

鯉の産卵数は種苗供給の計画を樹立するための基本となる。従来，重量法に依つて孕卵数を測定した結果が報告されているが，鯉は第1回の産卵で，すべての卵巣卵を放出しないから，孕卵数を産卵数とすることは不適当であるので両者の関係を検討し親魚の選択並びに産卵数算出の参考に供する目的で研究を試みた。

測 定 方 法

親鯉の産卵前の体重（W_0）と産卵後の体重（W_1）及び魚卵1瓦中の卵数（n）を測定し，第1次産卵数 $N=n(W_0-W_1)$ で算出した。

産卵後，魚体に残存する卵巣重量を秤量し，同様重量法に依つて，残存卵巣卵数（N_1）を求めた。従つて孕卵数は $N+N_1$ で表わされる。但し，n は10回の平均値を求めた。供試魚の飼育年令は4才乃至8才で雌魚1尾に雄魚2—4尾を交配して産卵せしめた。

※ 水産講習所研究業績 第17号，1957年7月25日 受理

測 定 結 果

第1次産卵数と体重との関係は第1表の通りである。

Table 1. Relation between the number of the primary spawning eggs (N) and the body weight.

Number of sample	1	2	3	4	5	6	7	8	9
Body weight (W_0) g	1050	1312.5	1500	1762.5	2062.5	2310.8	2550	2625	2625
W_0-W_1	75	99	99	55		300	337	231	231
N	63,450	79,313	63,312	50,820	232,400	277,200	311,850	195,750	195,750

10	11	12	13	14	15	16	17	18	19	20	21
2700	2737.5	3187.5	3225	3600	3750	3750	3787.5	3900	3937.5	4500.1	4762.5
356	225	525	487	337	515	281	225	432	497	497	732
101,640	282,975	240,617	485,100	450,450	285,525	365,400	259,875	285,620	240,617	452,454	618,887

体重に対する第1次産卵数は可成り大きい変異が認められる（第1表）。このことは即ち，雄魚の求愛行為に刺戟され，雌魚が完全成熟をなさず，産卵を余儀なくされる場合或いは，雌魚がたとえ完全成熟状態にあつても，雄魚が未成熟の場合には，放卵に必要な刺戟行為の弱化に依つて，充分に放卵されない場合等親魚の成熟程度と密接な関係があるものと考えられる。第1次産卵数は，体重に対してシグモイド曲線を示して増加する傾向が見られその範囲は5万粒乃至62万粒である。遷点法* に依つて，第1次産卵数（P）と体重との関係式を求むれば次式が成立する。

$$P = \frac{651.800}{1+e^{3.500-0.953W}}$$

1年間の産卵数に就いて日暮（1912）は3，40万粒，阿部（1932）は15～50万粒，内田（1939）は5～10万粒，松井（1948）は35万として何れも定説がないのは供試魚の成熟度及び体重の相違に基くものと考えられる。

第1次産卵数（N）と，残存卵巣数（N_1）との関係を表示すれば第2表の通りである。

Table 2. Relation between the number of the first spawning eggs and the remaining ovarian eggs.

Body weight W_0 (g)	Number of primary eggs (N)	Number of the remaining ovarian eggs (N_1)	Ovarian eggs ($N+N_1$)	Remaining percentages $\frac{N_1}{N+N_1}\times 100$	Age
3187.5	240,617	258,795	499,412	51.9	4
3787.5	388,064	105,639	493,703	23.1	4
3937.5	232,400	150,412	382,812	39.2	5
2310.8	528,454	81,584	609,938	15.4	8
4500.1	419,875	143,014	562,889	35.7	4

* 本所佐藤猛郎助教授の教示に依る感謝の意を表する。

残存卵巣卵数は孕卵数の 15.4%～51.9% を占め，卵巣の成熟程度に依つて可成りの大きい差異が認められる。此等残存卵巣卵は産卵後に於ける親魚の栄養状態，水温及び雄魚の求愛行為の頻度とその強弱に従つて，第2次，第3次或いは稀に第4次産卵が行われる。然し，好ましくない条件下では，残存卵巣卵は過熟卵となつて体内に吸収される。従つて，鯉の産卵回数は産卵時期に1回又は2回と称せられ判然としないのは，以上のような条件に支配されるためであつて一律に論ずることは困難である。

日暮（1934）は条件がよければ1日又は2日間に全部の卵巣卵を放出するとしたが著者の実験ではかかる例は認められなかつた。松井（1948）は産卵前の成熟鯉の卵巣は，成熟卵が93.3%，未成熟卵が6.7%で，産卵後の卵巣では成熟卵は殆んど産出され，未熟卵が残存していることを観察した。このことは次の実験に依つても立証される。即ち著者は成熟鯉に脳下垂体前葉ホルモン注射に依つて排卵促進を行い，全孕卵数を全部搾出して人工授精した場合，未熟卵が存在するため屢々低率の受精率を示すことである。

鯉の孕卵数に関し既往の業績を表示すれば第3表の通りである。

Table 3. Number of the ovarian eggs.

Authors	Body length or body weigth	Number of the ovarian eggs	Notice
J.Kawabata	46cm ; 1,275 g	230,000	
	52.8cm ; 1,688 g	440,000	
	59.4cm ; 3,750 g	600,000	
T. Higurashi	1,961 g	443,930	
Y. Matsui	1,368 g	186,265	Six years old, red coloured carp.
	47.5cm ; 2,813 g	385,464	Eight years old.
	48.0cm ; 28,125 g	590,309	Six years old, german carp.
K. Abe		300,000—700,000	
T. Wainai	64.5cm ; 7,100 g	678,686	Pond cultured 15 years.
K. Uchida	5580cm ; 3,500 g	300,000—400,000	
K. Fujita	Weight of ovary 250 g	240,000	
	Weight of ovary 750 g	340,000	

著者の実測値と既往の記録（第3表）に基いて孕卵数（O）と体重（W）との関係式を求むれば次の通りである。

$$O = 735{,}300\left\{1 - 0.732^{-0.374(W-1)}\right\}$$

産卵数曲線が抛物線を示すものと仮定すれば，体重 4.5kg程度で産卵数曲線と孕卵数曲線とが交叉するが，かかる現象は生物にあるべきではないからシグモイド曲線を示す性質のものと考えるのが至当であろう。産卵数曲線と孕卵数曲線の両曲線の傾向から体重が増加するに従つて，両曲線は接近する。即ち残存卵巣卵数が減少して産卵数が増加する傾向がある。かかる点からすれば産卵に供試する親魚は，少くとも体重 4kg 以上のものを選ぶことが適当と考えら

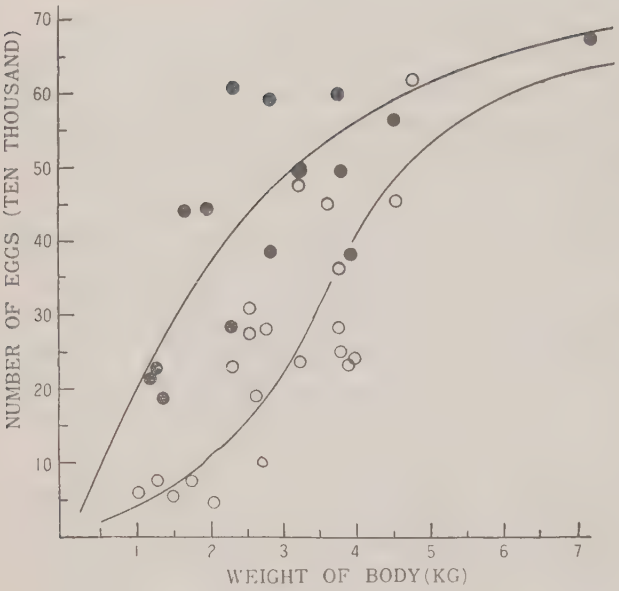

Fig. 1. Relationship between the number of the primary spawning and ovarian eggs and the body weight. ●, number of the ovarian eggs. ○, number of the primary spawning eggs.

れる。

孕卵数の左右の卵巣の測定結果は第4表の通りである。

即ち，卵巣及び孕卵数の左右不相称が認められ，右卵巣が重く而も孕卵数が多い。かかる傾向は，ヒメマス，マス，ニヂマス，カワマス，ウナキなどで認められた事実と一致する。

Table 4. Comparing with left and right ovary.

Items	Left ovary		Right ovary	
Body weight (g)	Weight of ovary (g)	Number of ovarian eggs	Weight of ovary (g)	Number of ovarian eggs
2278	190	126,730	221	160,446
1200	130	102,735	140	112,700

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On the Records of a Leptocephalus and Catadromous Eels of *Anguilla japonica* in the Waters around Japan with a Presumption of their Spawning Places※

By

Isao MATSUI

1. Introduction

GRASSI and CALANDRUCCIO (1896) obtained proof that *Leptocephalus brevirostris* KAUP is the larva of an eel, and subsequently SCHMIDT (1906—1935) investigated its life history on the basis of many collections from larvae of Europeo-American, South-Pacific and Indo-Malayan eels by his various contributions and after his death, EGE (1939) and JESPERSEN (1942) pursued the collections secured in his expedition round the world during 1928—1930 for further researches.

The former reported "A Revision of the Genus *Anguilla* SHAW, a systematic phylogenetic and geographical study" and the latter reported "The Indo-Pacific Leptocephalids of the Genus *Anguilla*". On the other hand the first collection by UCHIDA (1925) concerning leptocephalus of *Anguilla japonica* was merely recorded and, although its earnest pursuit has been made until now, it has not yet been collected as evidence. Presumptions concerning the spawning places by MEEK (1916), SCHMIDT (1925), OSHIMA (1941), JESPERSEN (1942) and MATSUI (1952) have not yet been established as a theory. The author is in a position to define the leptocephalus of *Anguilla japonica* in Japan and has conducted a survey of the catadromous eels caught in the waters around Japan.

The author, from their probable spawning places, has made a report here based on the above-mentioned results. Before going further, the author wishes to acknowledge his indebtedness to Prof. Dr. K. UCHIDA of Kyushu University who had the kindness to lend him his valuable sample of leptocephalus with useful advice, to his colleagues Prof. T. CHIBA and Instructor H. MAEDA who submitted a leptocephalus to the author, to Mr. K. WATAUCHI of Miyazaki Prefecture Pelagic Fisheries Guidance Station, to Mr. T. ITO of Yamaguchi Prefectural Open Sea Fisheries Experimental Station, and to Mr. H. HIROTA of Nichiro Fisheries Co. for their great assistance in collecting samples of catadromous eels.

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Thanks are also due to Mr. S. NISHIKAWA of our college who helped the author in making the preparations of the genital gland.

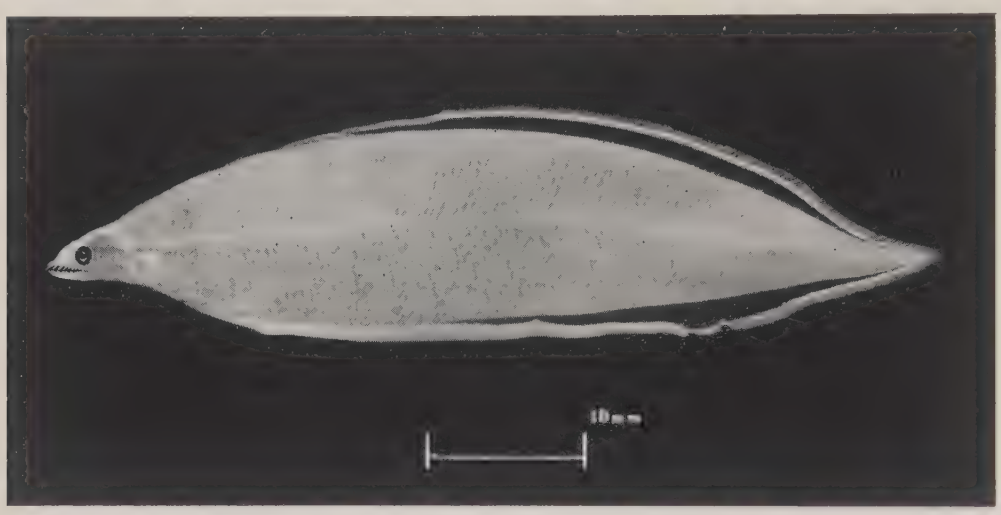

Fig. 2. Photograph of the leptocephalus of *Anguilla japonica*.

2. The diagnosis of the leptocephalus of *A. japonica*

While the survey of effect on radioactivity in the waters around the Bikini Atolls was being conducted by the "Shunkotsu Maru" during May—June, 1956, a specimen of leptocephalus of *Anguilla japonica* was collected by the collecting-net for macroplankton, measuring 150cm in diameter, 450cm in length, bolting silk GG 56, and mesh $54\frac{1}{2}$. The collecting-net had a 3.5kg lead sinker attached to its lower part and a 170m rope tied to its upper part, and was put down into the sea over 4,000 m deep, while the vessel was sailing at a speed of 24—42.5 m/min, and pulled up vertically. It was June 25, 1956 when the fish was caught for specimen in the shallower sea about 150 m deep lying between the Uracas and the Volcano Islands, 142°40′ E, 23°15′ N.

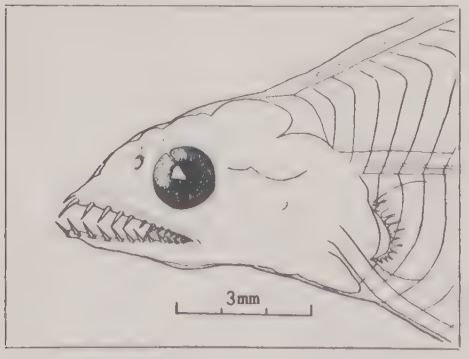

Fig. 3. Head region of the leptocephalus, especially showing the dentition.

The hydrographic conditions which were observed by HORI and SHIMANO (1956) at that time are given in Table 1 and Fig. 1. Water temperature was 20.63°C—29.4°C. Salinity 19.43—19.54‰ comparatively high temperature and salinity. The author has followed JESPERSEN (1942) in examining the specimen and the results obtained are given in Table 2. This specimen is 55.7mm in total length and, as shown in Fig. 2, looks

like a small leaf, very broad for its length and very thin for its breadth, the total length being 3.8 times as long as the maximum height in the center of the body and narrowing roundly both in posteriority and anteriority.

The top and tail are somewhat tapering, postanal length being 28.2% and myotomes numbering 120, with 79 at preanal portion, and 34 at anodorsal distance. The snout is moderately pointed, the lower jaw projects more slightly than the upper one, and the posterior maxilla attains towards far behind the center of the eye, but not towards the posterior margin of the eye. Eyes appear round. Tangue is distinct. A large grasping tooth is situated on

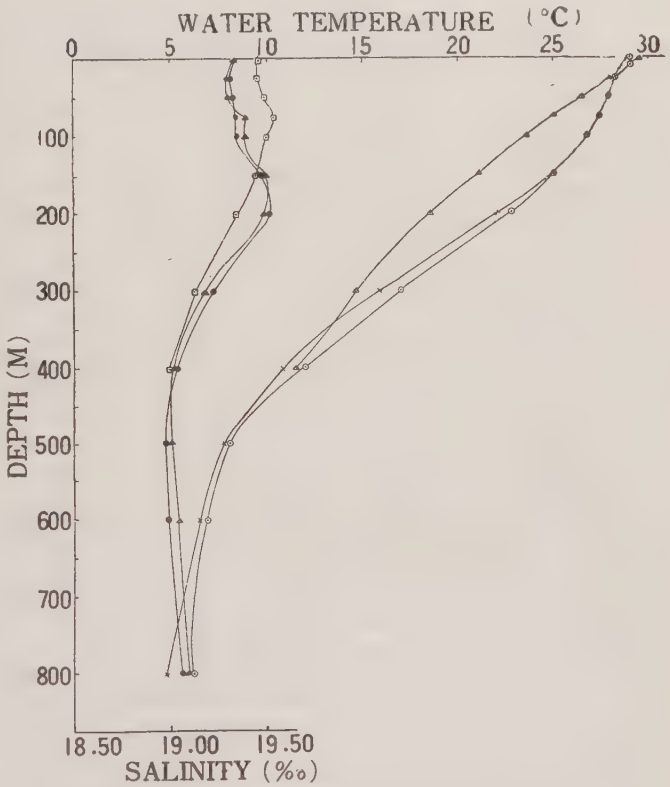

Fig. 1. Vertical distribution of temperature and salinity of the sea where the leptocephalus was caught.

Table 1. Oceanographical condition in the waters where the leptocephalus was collected (after HORI and SHIMANO 1956).

Date of observation	June 24, 1956. 19 h 20 m—21 h 00 m			
Locality	19°00′ N, 145°23′ E			
Depth (M)	Temperature (°C)	Cl (‰)	6 tD	Dynamic depth
0	29.4	19.46	22.07	0
10	29.04	19.45	22.23	9.783
25	27.93	19.45	22.63	24.454
50	26.42	19.49	23.30	48.893
75	25.09	19.54	23.90	73.317
100	23.56	19.50	24.39	97.727
160	20.63	19.43	25.23	146.517
206	18.22	19.32	25.99	195.268
302	14.58	19.12	27.04	292.685
400	11.43	18.99	27.99	390.007

Table 2. Morphometric measurements, counts of myotomes and proportional ratio of bodily parts for the leptocephalus of *Anguilla japonica*.

Total length	55.7mm
Standard length	54.9mm
Greatest depth	14.8mm
Length from tip of snout to origin of dorsal fin (D)	25.9mm
Length from tip of snout to origin of anal fin (A)	40.4mm
Ano-dorsal distance	14.5mm
Length of pectoral fin	1.8mm
Diameter of eye	1.3mm
Ano-dorsal distance/Total length	25.9
Number of myotomes	120
Number of preanal myotomes	79
Number of myotomes in ano-dorsal distance	34
Situation of vertical blood vessels	15,46,49,59
Dentition	1+4+8

each anteriority of the upper and lower jaws, and there is a row of 4 large teeth behind the grasping tooth in the upper jaw, behind which is another row of 8 smaller teeth (see Fig. 3).

In the lower jaw the teeth behind the grasping tooth are, more than eleven in number of uniform size, gradually decreasing in size posteriorly. The dental formula is 1+4+8. There is one comparatively large nostril and the pectoral fin appears oval in shape. Both dorsal and anal fins are emerged enough and the rays of the pectoral fin numbering 15 are also apparently seen. The pigment is wanting.

The specimen possesses the above-mentioned formal diagnois, which is discussed below in detail. The number of vertebrae, as seen from the researches by SCHMIDT (1909), (1925) and EGE (1939), is of the greatest importance in determining the species of the eel. JESPERSEN (1942) showed that it was a significant cause for the number of myotomes, which is closely related with vertebrae, in determining leptocephalus; it is estimated that on the average the number of vertebrae is one less than that of myotomes. Eight species of the eel widely distributed in the waters around the northern hemisphere of the Pacific Ocean, including the Banda Sea, the Celebes Sea, the South China Sea, the Sulu Sea, the Mindanao Sea, the Molucca Passage, north west of New Guinea, the Bay of Siam, Formosa and adjacent territories, the East China Sea, the Yellow Sea, the Pacific Ocean, and the Japan Sea, were reported by EGE (1939). Their numbers of vertebrae are given in Table 3. As to the number of vertebrae of the eight species, *A. japonica* can be apparently distinguished from the other seven species. *A. japonica* is the only species of which the number of vertebrae is more than 110. The Japanese eel may be divided in two species: temperate *A. japonica* and tropical *A. marmorata*, which are widely distributed in the South Pacific Ocean and the Indo-Pacific Ocean. The number of

Table 3. Ano-dorsal distance and number of vertebrae in species of *Anguilla* from Japan, Eastern Indo-Malaya and New Guinea.

Species	Ano-dorsal distance % in total length	Number of vertebrae	
		Variation	Average
Anguilla japonica	9.2	112—119	115.8
A. marmorata	16.3	103—109	105.5
A. borneensis	11.5	103—108	105.5
A. interioris	13.0	104—107	105.4
A. celebesensis	9.0	101—107	103.4
A. ancestralis	9.6	101—106	103.3
A. bicolor pacifica	0.2	103—110	107.2
A. obscura	3.6	102—107	104.0

vertebrae of *A. japonica* is as follows; 112—119, average 115.376 ± 0.062 by SCHMIDT; 111—119, average 115.65 by ISHIKAWA and TAKAHASHI; 112—119, average 115.888±0.404—116.111 ± 0.106 by MARUKAWA; 112—119, average 115.818±0.034 by EGE. As to that of *A. marmorata*; 110—107 by ISHIKAWA and TAKAHASHI; 99—107 by TAKAHASHI; 100—110, average 104.647±0.064—106.444±0.048 by EGE. It is apparent from the figures given above that we can tell the one from the other with 110 as the point of distinction. Vertebrae are numerous in *Apodes* except the eel. For example, the vertebral number of *Conger myriaster* amounts to 139—147, and that of *Rhynchocymba nystromi nystromi* to 113—124, *Oxyconger leptognathus* holds 111—119, but it can be easily distinguished from the pigmentary distribution, external characteristics, and especially from the anal position, body height and head length.

As the number of myotomes of the specimen is 120, the number of vertebrae in case of variation of this specimen indicates 119. The number of myotomes, according to UCHIDA's specimen (1935), coming to 118, the vertebral number amounts to 117, which indicates the approximate value, and is involved in the range of the variation of the vertebral number of the *Anguilla japonica*. BRUUN (1937) mentioned "that the figure and photograph of a leptocephalus which had been given by UCHIDA(1935) afford sufficient grounds for saying with certainty that it is not an *Anguilla*'s leptocephalus. One does not need to be able to read the Japanese text, the pigmentation above the brain and the characteristic, rounded tail show definitely that the larva must be referred to *Muraena* or its allied genus". And JESPERSEN (1942) agreeded with his opinion. The author has investigated this by using UCHIDA's specimen, and found that the part of the tail appears round in its photograph of his papers, though not so in the original specimen, and that the tail tapers off, as UCHIDA described in Japanese. As indicated by BRUUN, we can safely say that the number of myotomes is the safe way of determining definitely whether or not a leptocephalus will belong to that of *Muraena* and its genus,

whose species have at least over 124 myotomes.

Another point of difference which the author has noticed is that the origin of dorsal fin is originated from the head in the adult fish and that the pectoral fin is laking. But the author is sure that UCHIDA's specimen corresponds to leptocephalus of *Anguilla japonica*. Comparisons between the author's specimen with UCHIDA's are given here to show how they differ in various points. In the total length, the former is about two times as large as the latter though they are fairly different in size, which shows the different degree of growth in them. The ratio of the height to the total length is 5.9 to 3.8, while the author's is fairly heavier than UCHIDA's. It is thought that in UCHIDA's specimen, the disappearance of the dorsal fin, the anal fin and some teeth is owing to different stages of development.

When the auther's specimen is compared with UCHIDA's one, the posterior end of the mouth cleft in the latter is located more behind than that of the former. The number of myotomes minus one is found in the range of variation of the vertebral number of *Anguilla japonica*, which does not make the numerical difference of vertebrae between these two specimens. But the number of myotomes at the postanal portion indicates the proportion of 79 to 70, the proportion of the total length and postanal portion corresponds each other. By SCHMIDT (1906) and STRUBBERG (1913), the leptocephalus of the eel was divided into six stages according to the degree of growth this specimen falls under 1st stage. Among the more temperate species of the Indo-Pacific, e. g. *Anguilla japonica*, *A. dieffenbachi* and *A. australis*, the length of the full-grown larvae is not known, but, judging from the length of the elvers, they are presumably somewhat larger than those of tropical eels in the corresponding stages and the average length of full-grown larvae of *A. anguilla* is about 75 mm and that of *A. rostrata* about 60—65 mm; hence this specimen is not a full-grown larva, being 55.7 mm in size by 1st stage, so it is presumed to be somewhat more grown than the 55.7 mm.

3. The collection of catadromous eels

It is generally accepted that the Japanese eel descends from the fresh water to the sea, suitable place for spawning towards the end of September until early in December. On January 20, 1954 HIRASAKA and HONMA (1954) caught catadromous eel in the sea at a depth of 250 meters off Awashima 139°11′E and 38°20′N. This is the only record in Japan concerning catadromous eels. The author has recently had eels sent by some fishermen who are interested in the eel which happened to be caught in the net mixed with other fish. The author has kept the eels as specimen, the records of which are given in Table 4.

A) The Period of catadromous migration

The catadromous eels in the sea, as seen from the records tabulated below were

Table 4. Records of the catadromous eels caught in the waters around Japan.

Date	Locality	Depth (m)	Depth caught	No. of specimen	Total length (cm)	Body weight (g)	Sex	Fishing gears	Remarks
Oct. 1939	Kumanonada	300		1			?	One boat medium trawl	
Sept. 24, 1952	NW 15 miles off Kawajiri, Yamaguchi	200	Surface	1	40.0	60	♂	Spoon net	School of 5 or 6 individuals
Dec. 5, 1952	NW 30 miles off Kochiga of Goto Is.	125	Surface	1	45.3	400	♂	Mackerels' pole and line	
Dec. 10, 1953	34°30′ N, 123°30′ E	80	80	2	80.7—79.5	880—900	♀	Otta trawl	
Dec. 15, 1953	28°30′ N, 124°40′ E	100	Surface	1	49.5	520	♂	Mackerels' pole and line	
Jan. 11, 1954	31°58′ N, 125°55′ E	70	0—70	1	75.5	770	♀	Otta trawl	
Jan. 20, 1954	38°20′ N, 139°11′ E	250	0—250	1	62.6		♀	One boat medium trawl	Hirasaka and Honma's report
Dec. 18, 1954	28°44′ N, 124°35′ E	88	Surface	3			♂2, ♀1	Mackerels' pole and line	Water temperature, 19.8°C
Dec. 20, 1954	28°45′ N, 124°37′ E	76	Surface	4	48.6—67.8	150—430	♂1, ♀3	Mackerels' pole and line	Water temperature, 19.2—19.6°C.
Jan. 10, 1956	27°35′ N, 124°15′ E	80	Surface	3	51.2	180	♀	Mackerels' pole and line	Water temperature, 18.8—19.0°C.
Dec. 22—Jan. 8, 1954—1956	27°50′ N—28°40′ N, 124°40′ E—125°02′ E.	70—80	Surface	8	47.2—74.5	143—540	♀	Mackerels' pole and line	Uchida's report

caught during the period between September 24 and January 20. As the oceanic conditions vary every year, they may descend to the sea for about a month from September 24 to December 5, or from December 18 to January 11. The first period of migration is about the end of September, but in the northern district of Japan early in September, silver eels leave the pool and water-course in the interior and descend by degrees towards the mouths of rivers, or those which live in the littoral lagoons and estuaries also reach the sea water. In the southern region down to the middle of Japan, they gradually descend slowly from the north to the sea and their downstream migration comes to an end.

Thus catadromous eels captured in the sea from the end of December to the middle of January may have descended from fresh water to the sea much earlier. HIRASAKA and HONMA's joint records have it that catadromous eels were caught in the northern waters of Japan on January 20, which shows that the fish descend from fresh water to the sea, extending over a long period of time and that their spawning also extends over a long time. On the other hand, though *A. japonica* is distributed fairly wide, it is presumed that catadromous eels captured in the East China Sea migrate downstream from the coast along the East China, especially along the northern coast of Korea, the continent of China, and the Japan Sea. Therefore, local temperature and salinity, alternation of day and night in particular, may make the period of migration different, compelling eels to make detours or to

stop in their course, thus retarding their migration.

B) The locality of collection

The author's record of catadromous eels captured in the sea is given in Table 4, Fig. 4. According to these, a vast range of variations are found in the area between the sea 15—30 miles off the coast and the mid-East China Sea.

The locality where eels have recently been caught in plenty is the East China Sea off about 270 miles west of the Amami Oshima, where various fishing vessels operate during December and February as it has proved to be a good fishing ground for mackerel. Fishermen in their fishing boats can not only see with gathering lamps eels swimming in the surface water layer in several schools, but also catch them easily with the spoon net or a dip net. It is impossible for us to know the depth of the sea where the specimens were collected by the otta trawl or the two boat trawl net. However as seen from many other demonstrations, they seem to swim near the surface layer. CLIGNY (1912) explained the fact that they habitually swim well off the bottom, and are out of reach of the trawls. As to the relation of the current to the location·where catadromous eels are found in abundance, the location does not lie in the main stream of the main currents, such as the Tsushima Warm Current, Kuroshio, and cold water of the Yellow Sea, but in the current rip between the Tsushima Warm Current and coastal current or between the Kuroshio and Cold Water of the Yellow Sea. ROULE (1937) showed that from rivers or littoral pools, eels are led to the sea by the out-going water, and FONTAINE and CALLAMAND (1943) and FONTAINE (1945) determined that they are less active by a rapid fall of the water temperature, and besides, eels' muscular strength slightly diminishes because their migration is made passive by the current due to the want of nutrition caused by their fasting, all this being responsible for their negative rheotaxis.

These facts show that catadromous eels in the sea travel round their spawning places through these current rip instead of following the strong current, such as the Japan Current and the Tsushima Warm Current. It is not due to the phototaxis, but to the ceasing of the movement caused by the powerful light that they are considerably caught under the gathering lamp in the mackerel pole and line fishing ground in the East China Sea. This is based on the fact that catadromous eels are more active by night than by day. The water temperature in fishing points out 18.8°C—19.8°C. Eels move with greater activity in high temperature than in low temperature, and catadromous eels seem to travel in pursuit of high temperature. The measurement of the collected eels is shown in Table 5. Judging from the vertebral number and the external morphological characteristics, each specimen seems to belong to *Anguilla japonica*. Its body length is 40.0 cm in minimum, 40.0—49.5 cm in male, 51.2—79.5 cm in female, its weight being 60g in minimum, 880g in maximum. The author (1952) examined the sexes of 11,097 Japanese eels, and

Table 5. Morphometric measurements (mm) and proportional ratios of bodily parts for the catadromous eels.

Date of collection	Dec. 20, 1954				Sept.24, 1952	Dec. 10, 1953	Jan.10, 1956
No. of specimen	1	2	3	4	5	6	7
Total length	62.6	67.8	60.8	48.6	40.00	79.5	51.2
Weight (g)	371	430	340	150	60	880	180
Head length	7.5	7.6	6.6	6.1	5.0	8.6	6.3
Length from tip of snout to origin of dorsal fin	19.1	20.2	7.8	14.7	12.4	23.2	15.6
Length from tip of snout to origin of anal fin	25.9	27.1	24.7	20.6	16.4	31.0	20.2
Greatest depth	3.7	3.8	3.6	2.8	1.8	5.0	3.1
Length of pectoral fin	3.0	3.6	3.1	2.8	2.2	4.0	2.7
Height of dorsal fin	1.7	1.8	1.5	0.8	0.3	1.2	0.7
Length of snout	1.55	1.45	1.32	1.25	0.82	1.97	1.27
Diameter of eye	0.74	0.70	0.67	0.70	0.54	0.79	0.56
Interorbital space	1.4	1.4	1.2	1.1	0.9	1.7	1.3
Girth of body	10.4	11.5	11.1	7.9	5.5	15.1	9.6
Width of body	3.3	2.9	3.1	2.2	1.6	4.2	2.6
Ano-dorsal distance	6.9	7.0	6.9	5.9	4.0	7.8	4.6
$\frac{\text{Ano-dorsal distance}}{\text{Total length}}$	11.0	10.3	11.3	12.1	7.4	9.8	9.0
Sex	♀	♀	♀	♂	♂	♀	♀

reported his results as follows: the percentage of emergence in the body length above 50 cm is 15 % in female, which has the range from 32 cm to 129.7 cm and 47 % in male which has the range from 32 cm to 57.5 cm. The *Anguilla japonica* is in the range of this variation. Its body is black in color, tinged with blue in the dorsal part and emitting some metalic luster in the lateral part, or at dorsal portion with bronzed black, its side part with golden color at both upper and lower portions from lateral line and ventral part with plain crimsom. The origin of pectoral fin is colored with golden luster, and greynish black with a purple sheen or bronzed black in the top portion and also in lip and snout, or some eels are colored black in opercula.

C) Maturity

The author (1952) examined the maturity of gonad of downstream eels of *Anguilla japonica*, and got the following results; diameter of eggs above 0.2 mm in the stage of ooplasma is 16.3 %, the width of testis above 3.0 mm is 18 %, on the other hand, diameter of eggs above 0.1 mm, yolk-granules are very little, and few or undeveloped is 30.6 %, the width of testis from 2.0 mm to 3.0 mm is 39.6%, diameter of eggs below 0.1 mm is 53.1 %, and the width of testis below 2.0 mm is 41.2 %; from these the author has mentioned that the catadromous group with the comparative matured stage in the fresh water occupies 17.3 %, and the catadromous

Table 6. Size of the ovarian egg (mm) for the catadromous eels.

Date of collection	Diameter of ovum (O)		Diameter of nucleus (N)		$\frac{O}{N}$	Number of nucleoli
	Maximum	Minimum	Maximum	Minimum		
Dec. 20, 1954	0.22	0.19	0.080	0.061	2.75	9—14
〃	0.21	0.17	0.068	0.057	3.08	9—22
〃	0.18	0.17	0.070	0.056	2.57	9—17
Jan. 10, 1956	0.27	0.23	0.084	0.065	3.22	15—32

migration group with the immature stage is 47.3 %, to which most of the fish belong.

The results obtained from the author's examination of the gonad are shown in Table 6. The egg is 0.17—0.27 mm in diameter with the mean diameter of 0.22 mm, the testis measuring 0.2 mm in width, which shows it to be in a stage of sexual maturity. (See PL. 1). But the author does not think that eels will rapidly mature for their transportation from fresh water to the sea and a sudden change of living during its catadromous migration with fasting. They differ in the developmental stage of sexual maturation even in the same district and local distribution.

D) Contents of the alimentary canal

As to the alimentary canal, nothing has been found but some debris in its inner wall, which shows us that catadromous eels will not eat during their downstream migration. Considerable changes must have been brought about in their digestive apparatus, as they cease eating from the beginning of their sexual maturation till the time of their migration.

SCHNAKENBECK (1943) and BERNDT (1938) have closely studied the consequent regression in various parts of the digestive apparatus. First of all, the intestine shrinks and loses some sinuosity which is found in the yellow eel. Its lining diminishes in thickness, and, becoming flaccid, sticks together in many places, which further diminishes the internal diameter. All the tissues become thinner and the cells as well as their nuclei diminish in volume.

4. Consideration on the spawning places

MEEK (1916) included the Japanese eel in the South Pacific Ocean eels as the same species, about the spawning places of which he stated that the currents would lead us to discover the spawning regions in the Indian and Pacific Oceans from the distribution of larvae and a text figure showing the spawning regions which he presumed. The spawning places are located somewhere in the vicinity of the waters 5°—10°S, 160°—170°E in the south hemisphire. SCHMIDT (1925) and JESPERSEN (1942) presumed the spawning regions of *Anguilla japonica* as follows: in the south of Japan there is an area with specially high temperature in the intermediate water

layer. The "Dana" found a temperature as high as 26.4°C at a depth of 100 meters; 23.4°C at 200 m ; and 18°C at 300 m at a station south-east of Formosa.

It is the northern branch of the North Equatorial Current which runs up along the south coast of Japan under the name of "Kuroshio," corresponding to some extent to the Atlantic Gulf Stream. SCHMIDT (1925) already called our attention to the fact that this warm, more salt water in the south of Japan is the most likely spawning place of the Japanese fresh water eel, *A. japonica*. But the specimen of eel larvae collected from the "Dana" does not contain larvae of this species, and we are unfortunately unable to confirm this theory.

OSHIMA (1941) mentioned that the spawning places may be situated somewhere in the Celebes Sea or the Philippines Trough.

And, the author (1952) presumed as follows: the distribution of *Anguilla japonica* is closely related with the movements of ocean currents, and the spawning places must exist in the sea area, directly or indirectly influenced by the Japan Current. If the Japan Current originates near lat. 20°N., the spawning places must be situated in lat. 20°N. or a little northwards. But according to the distribution they seem to be situated south of lat. 30°N. If I were to determine the spawning places of the *Anguilla japonica*, taking into consideration the ocean currents, the depth of the sea, water temperature, salinity, etc., I would come to the conclusion that the most favorable water conditions for the fish are found south of lat. 30°N, not far from the land : hence the sea area, west of the Bonin Islands and near the Satsunan waters, which can easily be reached and in which the main Japan Current does not run, is the likeliest spawning places of the fish.

Concerning the spawning places of the *Anguilla japonica*, we have had no other contribution than the ones mentioned above. The author has tried again to examine those based on the records of the leptocephalus and catadromous eels captured in the sea. Localities where leptocephalus and catadromous eels of *Anguilla japonica* have been collected are given in Fig. 4. As to leptocephalus, UCHIDA's specimen was found in the Kuroshio, while MATSUI's specimen, to the south-east of the place where UCHIDA's was collected, and in the waters where the branch of the North Equatorial Current turns to the north-east. The two specimens are remarkably different in size as follows: UCHIDA's sample 24.8 mm and MATSUI's 55.7 mm. It is not proper to compare the two specimens about their size, for they were not collected in the same year. It is not thought that their variation in size, as in the spawning places of the Europeo-American eel, is proportional to the distance from the spawning regions. On the contrary, Indo-Pacific larvae collected at the same time and in the same place vary considerably in size. JESPERSEN (1942) pointed out that this fact was due to the following three viewpoints ; the different rate of growth of larvae, the different distance from the shore of the spawning areas and the different period of the spawning time. As to *Anguilla japonica*, the

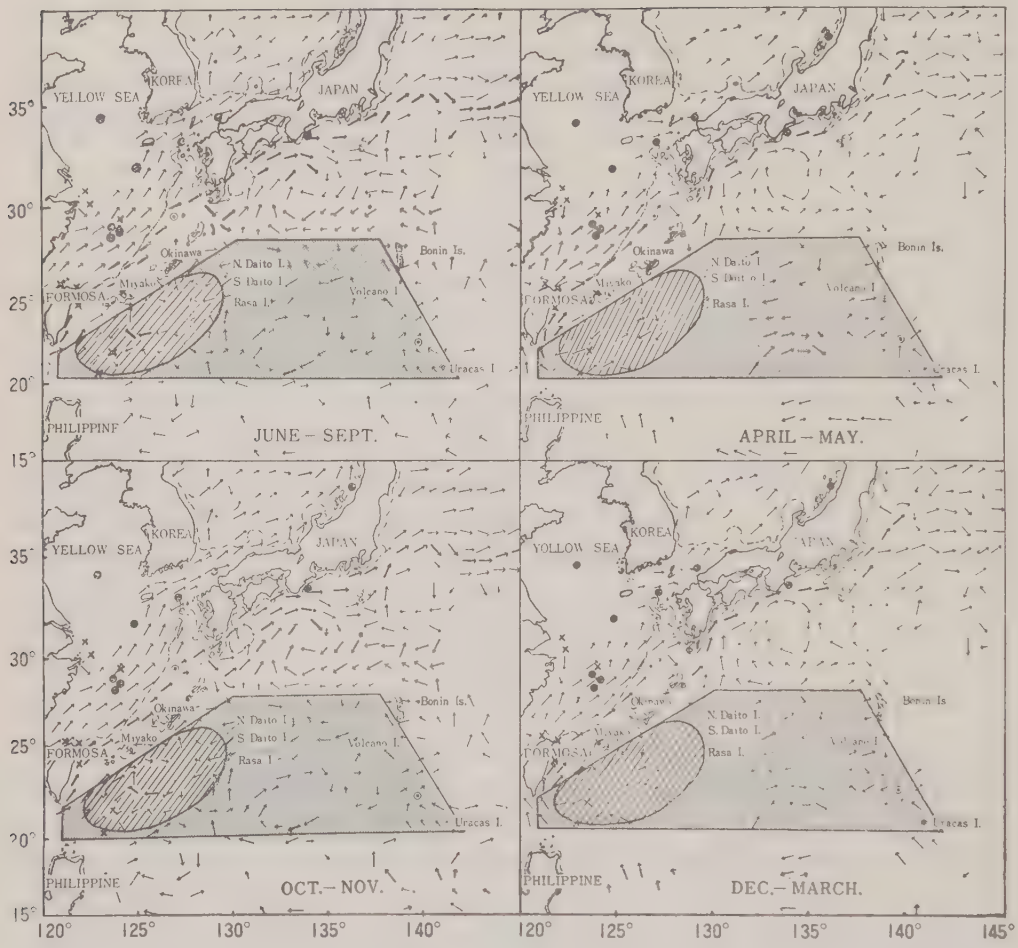

Fig. 4. Map showing seasonal changes of the oceanic currents in the waters around Japan, and localities where the leptocephalus and catadromous eels were examined in this study, and the presumptive area of Japanease eel.

◉ where the leptocephalus examined by Uchida and Matsui respectively, were collected ; X, stations where the Dana Expedition was done; ●, places where the catadromous eels were caught; stipplings show the presumptive spawning area ; shadings show the most probable spawning places.

distance from the shore of the spawning areas and the period of the spawning time are important factors.

The author (1952) mentioned as follows : The upstream period of the glass eels begins early in October and ends in the latter part of May, the size of glass eels during the period showing 56.73±0.17 mm—58.75±0.14 mm, and the upstream period extending to the long term is due to the long term of spawning time. This is one of the proofs that the spawning places are in the sea close by Japan proper. The upstream period of Japanese eels begins earlier than that of European eels. JESPERSEN (1942) mentioned that the spawning period of the tropical species covers the greater part of the year, or possibly the whole year, while for the more

temperate species in the Indo-Pacific as the Atlantic it depends on the season. The upstream period of glass eels is long, but no visible difference is noticed in their size during that period. From this, the author has presumed that the spawning time of *Anguilla japonica* is between that of the Europeo-American and that of the tropical eels. According to SCHMIDT (1925) it is apparent that, so far as the spawning area is concerned, very young leptocephali cannot be caught except in the period between March and July. They are not caught in autumn or winter, so the spawning of eels must begin in spring and continue for about five months until the middle of summer.

The leptocephalus of *Anguilla japonica* is collected from the end of May to that of June, as is the case with Atlantic eels. From the above account and the upstream period of glass eels, the spawning time begins early in spring and continues until early in summer. SCHMIDT (1925) and JESPERSEN (1942) gave the following as the favorable conditions for eels' spawning places: the depth of water is at least above 4,000 meters and, though the eggs are fertilized at a depth of 400—500 meters, very young larvae just hatching from them rise to the surface without delay. Those which measure 5 to 15 mm are mostly caught at the sea 300 and 100 meters deep. A little bigger ones, or a little grown-up ones, are caught still nearer to the surface, generally at a depth of 50 meters or so with a temperature of less than 15°C. It does not seem possible that eels find the favorable place for spawning. That part of the sea which is above 4,000 meters deep and the temperature of which is above 15°C during the period between February and June may be considered to be a favorable place for eels' spawning.

Thus the author has observed the high temperature in the sea around Japan, especially along the Pacific coast in the above period. SCHMIDT (1925) presumed that the spawning ground of *Anguilla japonica* is distributed in the high temperature waters of the Pacific Ocean, because the high temperature waters of 13°C at a depth of 400 meters are found in the Pacific Ocean near Japan and there exist the

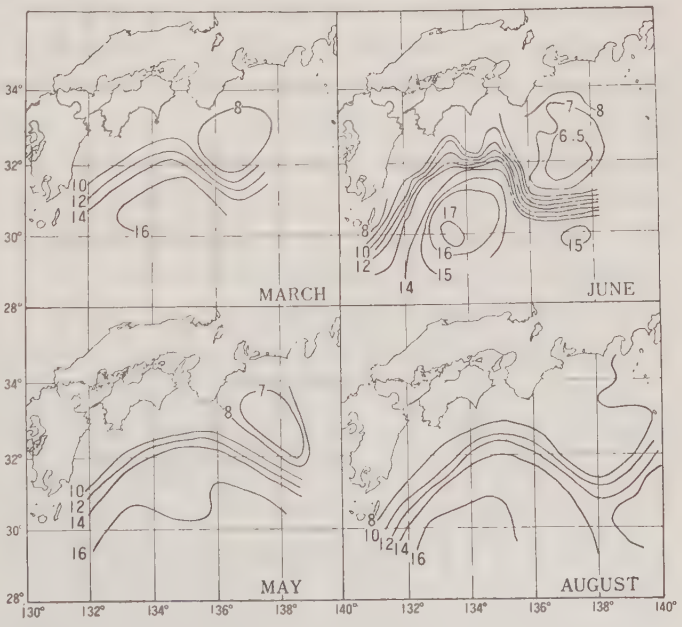

Fig. 5. Map showing the distribution of temperature at 400 meters depth in the water off south Japan.

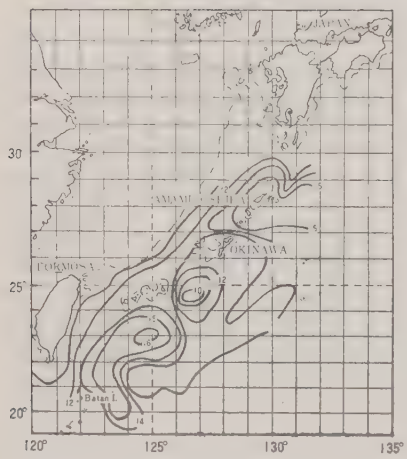

Fig. 6. Map showing the distribution of temperature at 400 meters depth in the water around the Loochoo Islands.

isothermal waters of 17°C in the Atlantic Ocean of America and its vicinity, analogous to the spawning place of *A. rostrata*. According to the recent report of the oceanographical investigation of Japan conducted in the southern waters, the isothermal layer of 16°C extends from the southward to the waters near lat. 34°N, where the cold water mass exists discontinuously (Fig. 5,6). It is recorded from the "Dana" expedition that the high temperature station exists in the southern extremity of Formosa. UDA (1940,'41) observed that the high temperature waters exist to the east of the Okinawa Islands outside the Kuroshio main stream. According to the investigations of IIDA et al. of Kobe Marine Observatory (1955), the isothermal layer of 16°C at a depth of 400 meters is distributed in the sea south of Japan all the year round. So far as the water temperature is concerned, the spawning place of *A. rostrata* covers the sea of high temperature above 16°C, as discovered by SCHMIDT (1925).

Though there is a water layer with a temperature of above 16°C at a depth of 400 m near the Pacific coast of Japan, the water temperature is not the only condition necessary for eels' spawning places, because eels have to depend presumably upon the ocean current for their distribution. In the northern waters around 28°N. and 29°N., where the Tsushima Current bifurcates and a branch stream of the Japan Current turns up to the Yellow Sea, eels may find their spawning places, but it is rather difficult for them to get distributed off the coasts of China, Korea and the Japan Sea. If the spawning place of *Anguilla japonica* has the water temperature above 16°C, as is the case with that of *A. rostrata*, they must be distributed in the southern waters between 28°N and 30°N.

As to the Europeo-American eel, the larvae, on being hatched, ascend towards the surface and are taken at an average depth of 50 meters in the daytime, and at a depth of 20—30 meters at night. The Kuroshio main stream runs at a velocity of 30—50 miles per day, so they can reach the coast of Japan from the spawning places in a short time. But the spawning places cannot be in the Kuroshio main stream, but necessarily in the waters accessible to it. The counter current and the maelstrom of the Kuroshio between the Japan Current and the North Equatorial Current are strengthened and a fairly complex tidal current exists, and the waters in the vicinity of this area, as seen in the above account, are high both in temperature and salinity. Consequently that part of the sea may be considered suitable for

the eels' spawning places. Under these oceanic conditions, UCHIDA's specimen was collected in the Kuroshio, while MATSUI's specimen, in some part of the Counter Japan Current, what is called the "Ogasawara Current".

Leptocephali are carried by the surface currents and the larvae are spread in all directions around the spawning area. But if leptocephali were to drift in the waters of low temperature and salinity unsuitable for inhabitation, they would die. But they manage to find suitable waters for inhabitation, and travel around the coasts of Japan and China. So we can safely say that the distribution depends on the waters adjacent to the Japan Current. The ocean current in that part of the sea lying between lat. 20°N. and lat. 28°N. has much to do with the author's presumption of the spawning place of Japanese eels, particularly so during the period between April and November, when the leptocephali approach the sea-shore after they are hatched. The spot where my specimen of the leptocephalus was caught was a little far away to the east of the above-mentioned area. Our sea examination conducted when the specimen was caught showed that a weak ocean current was heading north-east to join the Counter Japan Current and finally the Japan Current near the Loochoo Islands. Elvers can presumably migrate from place to place by means of these currents. Those catadromous eels which have often been caught in the fishing ground for mackerel in the East China Sea to the west of the Loochoo Islands in December and January have easy access to their presumable spawning places, taking advantage of the weak ocean current heading south between Okinawa Island and Miyako Island of the Loochoo Islands. Taking all these into consideration, presumable spawning places of Japanese eels may be in the range lying between lat. 20°N. and lat. 28°N. and between the Loochoo Islands (long. 125°E) and the Bonin Islands (long. 140°E). The most probable spawning places of the eel in this range may be in the sea, oval in shape, bounded on the west by Formosa and the Loochoo Islands with their Trench and bounded on the east by an imaginary line extending downwards from North Daito Island to Lat. 20°N. with South Daito Island and Rasa Island on its way.

Acting on this presumption, the author is planning to determine the spawning places of Japanese eels, investigating the sea on board the training ship of our college. In the event of this plan being put into practice, the spawning places of Japanese eels will be made clear, it is hoped.

(The author wishes to heartily acknowledge his assistance rendered in the studies on the vertebral number of Apods except the eel (See 155 p.), which has been investigated by Ass. Prof. T. Takai.)

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Notes on Retino-motor Phenomena in Some Fishes under the Various Light Conditions※

By

Hiroshi KOBAYASHI

Since BOLL (1877)[2] and KÜHN (1877)[9] found that the rods, cones and retinal pigment of vertebrate exhibit marked changes of position in light and darkness, the shifting of these visual elements of fish in light and dark adaptation was measured by v. FRISCH (1925)[5], WUNDER (1926)[14], STUDNITZ (1933)[10] and others; and their researches contributed to the physiological studies of fish vision such as "Duplicity Theory", visual acuity, etc.. However, these works were the experiments using fresh water fish, and moreover there are no systematic and quantative measurements on the relation between the moving ratio of visual element and the intensity of the illumination, though BRUNNER (1934)[3] observed the elongation and contraction of the cone in lower intensity. Therefore, from the viewpoint of fundamental investigation regarding the effects of fish gathering lamp, the author made experiments in some fishes including the marine fish in order to investigate the differences between fish species, and it seemed necessary that he should consider these results as compared with the relation between the moving ratio of visual element and visual acuity curve of *Phoxinus* measured by BRUNNER. And thus the moving ratio of the visual element in relation to the intensity of the illumination and the time relation of light and dark adaptation in their elements are explained in present paper.

It is a pleasure to record here a debt of gratitude to Professor Dr. N. Y. KAWAMOTO, prefectural University of Mie, for his supporting of my work and for his kindness in revising the manuscript.

Material and Method

Materials used in this work are silver mackerel, *Trachurus japonicus*, crusian fish, *Carassius auratus*, loach, *Misgurnus auguillicaudatus*. Their body length is about 10—12 cm, 3—5 cm and 10—12 cm, respectively. Experiment was made in a dark room in the day-time. Four fishes are held in glass tank which is 35 cm in diameter and 15 cm in depth. Water in the tank was not running during

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the experiment. From the consideration of individual variation, the moving ratio was measured with four fishes. But the number of the fish in the tank was in point judging from the respiratory condition in the tank during the experiment. The lamp, MATSUDA 2 c.p., used as light source, was suspended on the straight line up from the tank. This illumination was adjusted by varying the distance between the lamp and the tank, and atso by using of the tracing papers as filters. For the light intensity was measured by YOKOGAWA'S Lux meter using a selenium photo-cell, but the value in dim light was calculated by Lambert's formula from the value measured in short distance. The retina of a fish was carefully removed following the cut and fixation of the head after various light conditions. Before the head was cut, the cornea of the eye was injoured in order that fixation solution could be enough penetrated. Fixation of the retina was rapidly taken in use of Carnoy's solution and imbeded into paraffine. The section was made in 7—8 μ thick and was stained by iron-haematoxylin and eosin. The ratio in the movement of the visual element was measured in adjacent part to center forvea by the horizontal section passing the optic nerve.

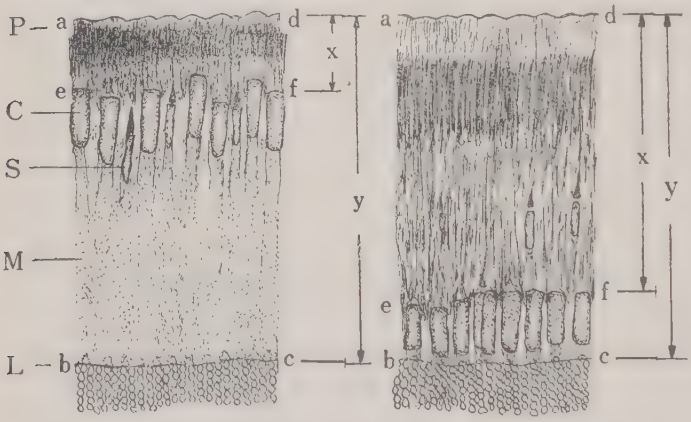


Fig. 1. Schema shows the positions of cones and pigment in the section of *Trachurus* in light (right) and dark (left) adaptation. The moving ratio of cone and pigment is indicated by $\frac{x}{y}$ and $\frac{\text{area aefd}}{\text{area abcd}}$, respectively. P, pigment; C, cone; S, small cone*; M, myoid of cone; L, external limitting membrane.

As shown in Fig. 1, the change in the position of the cone was indicated with percentage of the distance from the base of the pigment epithelium to the distal point of the cone ellipsoid to the distance from the base of the pigment to the external limitting membrane. Thus, the shifting of the cone was measured by about twenty ones per one individual and the average was put out. As for the moving ratio of the pigment, a certain part of the retina was made in a sketch by Abbe's drawing apparatus and then the area of pigment layer was measured by means of a planimeter. Thus, the moving ratio of pigment was calculated by the percentage of the area of the pigment layer to the total area from the base of the pigment epithelium to the external limitting membrane. All the experiments were carried out from noon to four o'clock p. m., considering the occurrence of the phenomena as described in KAWAMOTO & KONISHI's report (1955), or from the persistent diurnal rhythm in the movement

* It is so called temporarily by the author.

of the retinal element as shown by AREY & MUNDT (1941).

Experiments were carried out from September to November of 1953.

Experimental Results

Relation between the moving ratio and light intensity: The fishes were illuminated with the various intensity of the illumination for 2 hours after 2 hours of dark adaptation and then the head was cut and fixed. The range of light intensity used in this experiment was the degree from 0.008 to 25 Lux on the surface of the water.

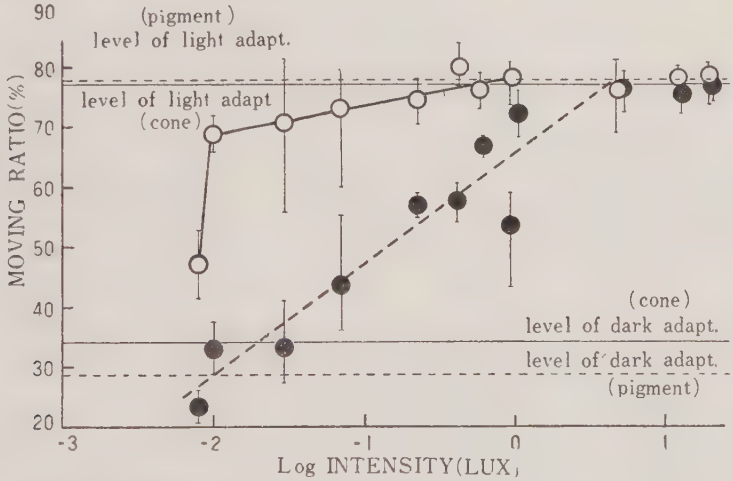
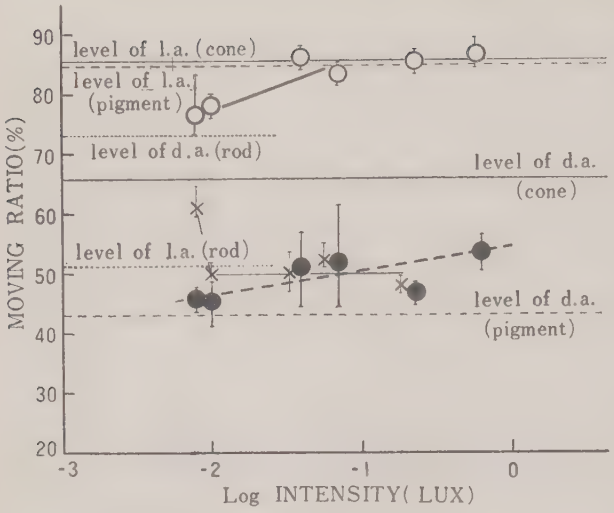


Fig. 2. Showing the moving ratio of cone (○) and pigment (●) in relation to the intensity of the illumination in the retina of *Trachurus*. The length of the vertical line at each point (average) shows the variation of measurement values. Water temperature is 17—20°C

The result obtained in *Trachurus* is shown in Fig. 2. When the light intensity decreases to 0.008 Lux, the cone shows elongation, and its moving ratio is 47 %. However, the cone takes contraction rapidly in 0.01 Lux of the illumination, and then it takes slowly contraction in proportion to the intensity of the illumination in the range of the more large intensity than 0.01 Lux. Thus at the intensity of more than 1 Lux, the cone shows the state of light adaptation. As for the pigment migration, it begins to expand at length from the state of dark adaptation when light intensity is given to 0.03 Lux, and in the intensity of 5 Lux, the expansion shows the state of light adaptation.

In *Carassius*, the cone does not show the complete elongation in 0.008 Lux, and then it becomes to the state of the light adaptation at the intensity of 0.23 Lux. Concerning the pigment migration, it shows the contraction in 0.008 Lux as well as dark adaptation, but the ratio of the pigment migration for the increasing of the illumination is very slow comparing with that in *Trachurus*, and it could



Fig, 3. Showing the moving ratio of cone (○), rod (×) and pigment (●) in the retina of *Carassius* in relation to the intensity of the illumination. Water temperature is 14—17°C. .

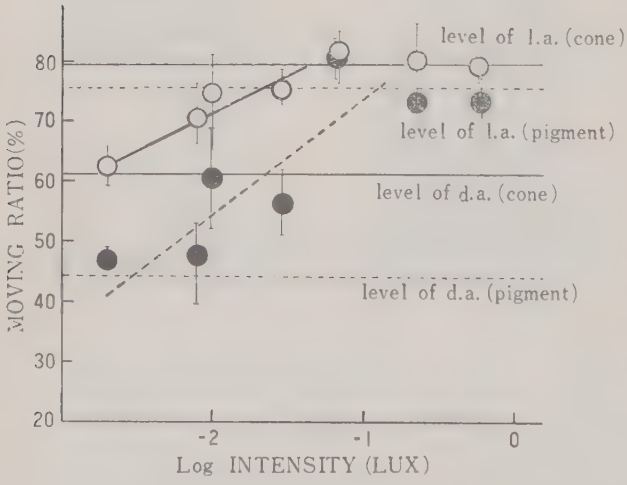


Fig. 4. Showing the moving ratio of cone (○) and pigment (●) in the retina of *Misgurnus*. Water temperature is 20– 23°C.

not reach to the state of the light adaptation in the range of the illumination shown with present experiment. The extension in which the visual elements change the positions according to the intensity of the illumination, is more small than that of *Trachurus*, particularly so in the cone. The rod elongates rapidly at 0.008 Lux, but it does not yet reach to the level of dark adaptation. Therefore, it is thought that the intensity, with which the rod alternates the position with the cone, is more less than 0.008 Lux. I am sorry to cannot find the alternate intensity owing to the circumstances of material.

The results in *Misgurnus* is simillar to that in *Carassius*, but the movement of pigment reaches to the level of light adaptation in 0.07 Lux, and also in 0.002 Lux both cone and pigment reach to the dark adaptation.

It is clearly seen that these visual elements move in proportion to the logarithm of the light intensity in certain range of the intensity, and moreover these shifting is not applied to the all-or-none principle.

Time relation of the movement in dark adaptation : It seems that there are no reports concerning the changes of visual elements which occur during dark adaptation of marine fish. Present experiments were made in order to investigate these morphological changes directly within the living organism. Still this experiment was made by the same method as in the former one. *Trachurus* were adapted in light of 50 Lux and 0.23 Lux for 2 hours respectively, and then retina of the fish was fixed

about every 10 minutes. These results were shown in Figs. 5 and 6.

These figures indicate that if the illumination of pre-adaptation is more intense, the time course of dark adaptation proceeds more slowly. The moving ratio was observed in central and marginal part(back)of the retina. However, the ratio of the visual element in latter part seems to be of high value ; namely, the movement of that element tends to be carried out rapidly. But, the time course seems to be the same in each course. Moreover, it should be noted that pre-adaptation to a light of high intensity is followed by a gradual dark adaptation course, and at the time of about 90 minutes it reaches to a stationary state, and a pre-adaptation to a light of low intensity is followed by a rapid course, and it reaches to the stationary state in about 40 minutes. It is interesting to note also that in 5—10 minutes after dark adaptation, the migration of the reversible direction is seen.

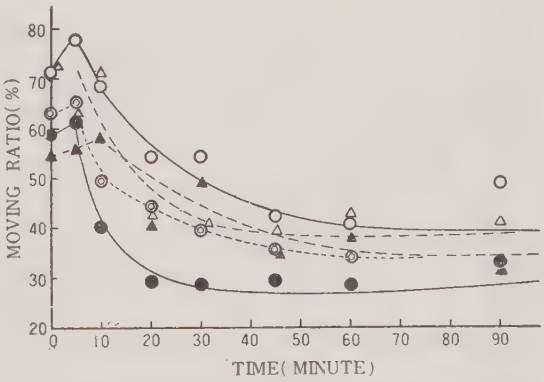


Fig. 5. Showing the time relation of dark adaptation of the moving ratio of the visual element in *Trachurus*. The fish was pre-adapted for 2 hours with the illumination of 0.23 Lux. The marks are as follows. ○, cone in the central part of the retina; △, cone in the marginal part; ◎, Small cone; ●, pigment in the central part; ▲, pigment of the marginal part. Water temperature is 17—20°C.

Time relation of the movement in light adaptation : Time relation of the cone and the pigment during light adaptation was observed after 2 hours of dark adaptation (Figs. 7 and 8). *Trachurus* was illuminated with light of 50 Lux and 0.23 Lux. In these results it is seen that the state of the light adaptation is formed more rapidly than that of the dark adaptation, and in the illumination of 0.23 Lux for one minute the cone already shows the contraction, but after 5—10 minutes it elongates slowly, and then it takes contraction again. This process agrees with the re-

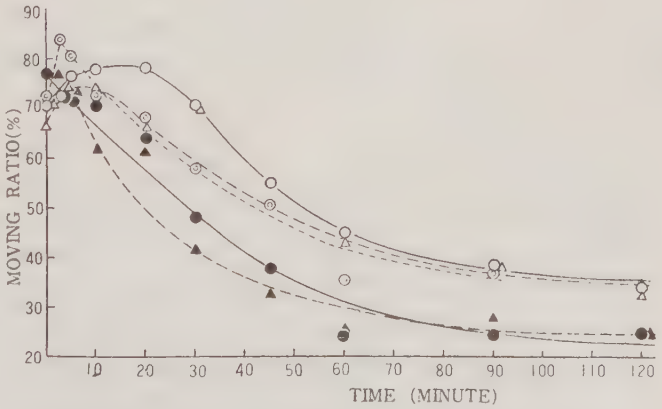


Fig. 6. Showing the time relation of dark adaptation of the moving ratio of the visual element in *Trachurus*. The fish was pre-adapted for 2 hours with illumination of 50 Lux. Water temperature is 17—20°C. The marks are the same as those of Fig. 5.

sult of STUDNITZ (1933).[11] However, on the contrary, the continuous process of light adaptation was obtained in the illumination of 50 Lux and reached to the state of light adaptation in about 30 minutes.

Discussion

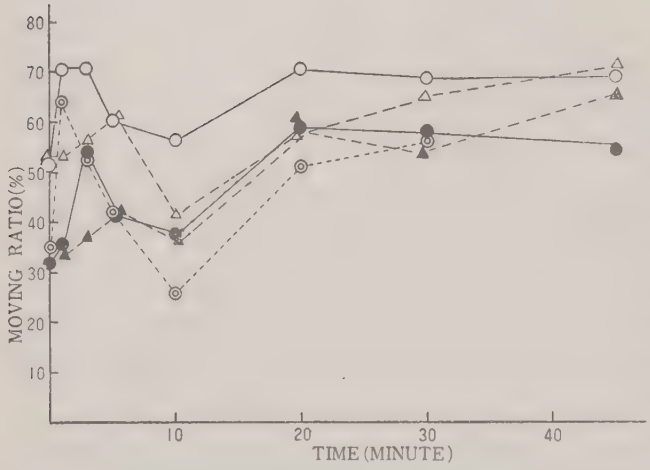


Fig. 7. Showing the time process of light adaptation of the moving ratio of the visual element in *Trachurus*. The fish was adapted for 2 hours with the illumination of 0.23 Lux. Water temperature is 17—20°C. The marks are the same as those of Fig. 5.

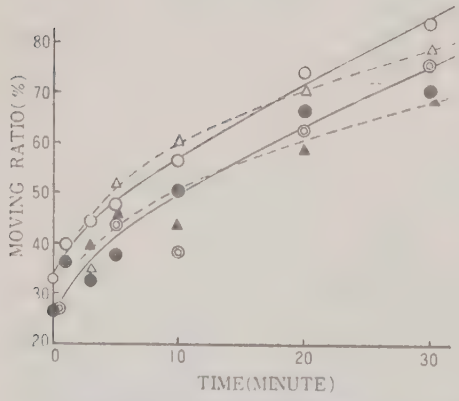


Fig. 8. Showing the time process of the moving ratio of the visual element in light adaptation in *Trachurus*. The fish was adapted for 2 hours with the illumination of 50 Lux. Water temperature is 17—20°C. The marks are the same as those of Fig. 5.

As described by PARKER (1932) [10] and DETWILER (1943),[4] the significance in the function of the retinal pigment exists in the absorption of light by the pigment rather than the support in the regeneration of visual purple; namely, the pigment is eliminating the light that would otherwise be disturbing to the sharpness of the visual image or overpowering in stimulation. And then, it is thought that the moving of the retinal pigment is also important for the investigation of fish vision. In the present work, marine fish was used as one of experimental materials. Therefore, the results of this experiment will give a fundamental thing to the studies regarding the effect of fish gathering lamp. And a few considerations will be described below as compared with the results of fresh water fish.

As shown in Figs. 2, 3 and 4, it is applied to the Law of Weber-Fächner that the moving ratio is linear in relation to the logarithm of the light intensity in certain range of the intensity.

It is assumed that white light used in this experiment may be changed in the composition of wave length in the lower intensity of the illumination, because the neutral filter could not be used for lowering

of the intensity. However, from HONJO's date[6] the range of the shifting of visual element in relation to wave length is about 10 %, particulary it is remarkable in yellow-orange light, and the direction of the moving shows the light adaptation. Therefore, the excess over the value observed in the present experiment will not occur in truth ; then the present results are thought to be due chiefly to the effect of the light intensity than that of the wave length.

The moving of the visual elements is different from fish species ; for instance, in *Trachurus*, the cone moves from 35% in dark adaptation to 85% in light adaptation; in *Carassius*, it moves from 65 % to 85 %. After a fast contraction of the cone in low intensity, the velocity of the cone-movement for the intensity is not different from each other, but the velocity of the pigment migration in *Trachurus* is larger than that in *Carassius*. It is also seen that the intensity with which these retinal movements reach to the stationary state is different in fish species.

Above mentioned fact may be in consequence of adaptation due to the ecological difference ; namely, *Trachurus* moves the long distance vertically. In other words, the fish moves up and down rapidly from dark place to light place. *Carassius* moves in the place where dark and light conditions are considerabl stable. Also this suggests that the role of the retinal pigment migration may be in the regulation of the ray of light incident upon the eye slit because of the fixed pupil in fish.

It is very interesting to note that the range of intensity of $1—10^{-2}$ Lux with which the movement of retinal element occurs remarkably agrees with the fact that the lower limitting intensity in which the *Trachurus* meet together to the fish gathering lamp is $1—10^{-2}$ Lux in open sea. [12]

Moreover, BRUNNER[3] investigated the relation between the visual acuity of *Phoxinus* and the light intensity, and found that the transition of the function between rods and cones occures in the intensity of 0.002—0.008 Lux. When this intensity is compared with the results obtained in the present work, it is noted that the intensity produceing the elongation of cones in *Trachrus* is very similar to this intensity. However, since the rods of *Trachurus* can not be found in the present writer's collections, it may be thought that the intensity mentioned above does not show the transition of the two functions, but shows the limitting intensity of photoperception. On the other hand, this interpretation seems to be confirmed from the fact that a-wave of electroretinogram of *Trachurus* disappears in this intensity[8]. Those intensities in *Carassius* and *Misgurnus* are lower than that of *Trachurus* (Figs. 2, 3 and 4) ; therefore this fact shows that their retina may be more sensitive as described in *Cyprinus* from ecological viewpoint by TAMURA.[13]

And also YAMANOUCHI [16] observed in *Microcanthus* that the site of transition between rods and cones occures in the intensity of 0.4—5 Lux. But, fishes used in the present work still show the decrease of the moving ratio of the cones and pigment below this intensity, and so the alternate of the two elements will occur

below this intensity. Therefore, it is assumed that these fishes have more fine visual acuity than that of *Microcanthus*.

The correlation was not found between the intensities where visual acuity becomes stationary and the shifting of visual element reaches to the stationary state.

Although time relation of dark adaptation is different from the light intensity and the duration of pre-adaptation light, it appears that the time of complete dark adaptation in fish is longer than that which has been generally considered. At 5—10 minutes after dark adaptation, the movements of the retinal element in reverse direction were seen ; however, these physiological significances were not considered. STUDNITZ [11] described that the contraction of the cone and expansion of the pigment in light adaptation does not show the continuous process, but in the present writer's experiment with 50 Lux, the continuous process was seen. This increpancy is not understood too. Moreover, in experiment of time relation, visual element was measured in both central and marginal part of the retina. Therefore, judging from these results (Figs. 5, 6, 7 and 8), it may be thought that the marginal part (back) of the retina is more sensitive than the central part, and the time relation of the central part is more rapid. This supports the TAMURA's results which the visual axis of *Trachurus* shows the fore direction at least.

However, the movement of these visual element does not always proceed in parallel with the decomposition and regeneration of photosensitive substances. Accordingly, though the function of photoperception could not be discussed on the data in the present report, it is thought that fish conduct for light stimulus is assumed to a certain degree from the retinal state under the various light conditions. Therefore, not only these morphological changes, but also electrophysiological or biochemical comparative researches of retina will be expected in the foreseeable future.

Summary

1) The movements of cone, rod and pigment in retina of fish, *Trachurus japonica*, *Carassius auratus* and *Misgurnus auguillicaudatus*, were investigated in relation to the intensity of the illumination.

2) The moving ratio of the cone and pigment is shown in proportion to logarithm of the light intensity in certain range of the low intensity, and these relations are applied to the Law of Weber-Fächner.

3) Movement of the cone is not applied to all-or-none principle.

4) The intensities of the illumination in which the cone contracts rapidly and the shifting of these retinal elements reaches to the stationary state, are different from each other in fish species. This seems to be the consequence of the ecological adaptation.

5) It was found that the intensity of alternative function in visual acuity curve

obtained in *Phoxinus* by BRUNNER, agrees with the intensity which occurs in the elongation of the cone in *Trachurus*. And in *Carassius* and *Misgurnus*, these intensities were lower than that of *Trachurus*.

6) It is seen that the degree of the illumination in which the cone and pigment move, coincides with the illumination where *Trachurus* comes to the fish gathering lamp in the open sea.

7) Time process of dark and light adaptation is observed in *Trachurus*. Dark adaptation is formed in 40—90 minutes by pre-adapted light of 0.23—50 Lux, respectively. Light adaptation is formed more rapidly than dark adaptation. Light adaptation with 50 Lux does not show a none-continuous process as described by STUDNITZ. The marginal part of the retina seems to be more sensitive than the center.

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山口県豊田湖(木屋川ダム)に於ける陸封鮎の生態学的研究—I※

藤　本　政　男

Ecological Studies on the Land-locked *Ayu* (*Plecoglossus altivelis* T. et S.) Propagated in Koyagawa Dam (Lake Toyota) in Yamaguchi Prefecture I

By

Masao FUJIMOTO

In May 1957 the writer caught a lot of land-locked *Ayu* coming upstream in the lower course of the River Tawarayama, which empties itself into Koyagawa Dam, or Lake Toyota in Yamaguchi Prefecture. This has made him confirm that the land-locked *Ayu* propagate themselves in the Dam. Koyagawa Dam is an artificial lake, or what is called a reservoir, built up by damming up the water in the upper course of the River 'Koyagawa' located in the western part of Yamaguchi Prefecture, thus keeping the fish from coming upstream from the sea. The dam covers an area of 1.066 square kilometers when it is full, its maximum depth being 39 meters. It is quite unusual that the *Ayu* fish propagate themselves in such an artificial lake, and the writer desires to develop the valuable fish resources by sending the fry of the *Ayu* to other lakes or rivers in our country for their reproduction, and has already set about investigating the *Ayu* fish from ecological point of view. The outline of the writer's study runs as follows.

緒　　言

陸封鮎は琵琶湖の外に，鹿児島県池田湖，鰻池，宮崎県御池，山梨県西湖[1,5]及び本栖湖等の天然湖沼に於いても多少ながら蕃殖することが知られている[1,5]。然し，人工湖に於ける小鮎の蕃殖は，筆者等が往年湖鮮総督府水産試験場に在勤当時，全羅北道東津水利組合雲岩貯水池に蕃殖させた記録[2]以外に報告がなかつたが，最近，筆者は山口県豊田湖（木屋川ダムの通称）に陸封鮎の蕃殖を確認し，その調査結果の一部を既に予報した[3]。今回は更にその後の研究を加えてここに発表する。

近年，吾国各地の河川に大小の人工湖沼が建設され，旧河川に於ける漁業権に対する補償或は新生水面の利用等に複雑な問題が屢々起きている。豊田湖に於ける小鮎の蕃殖は現在の吾国の人工湖では最初の記録であるが，後述の如く，豊田湖は小規模のダムであるにかかわらず，小鮎の発生は可なりの数量に達し，従つて，鮎の陸封蕃殖に恵まれた条件を有していると思わ

※ 水産講習所研究業績 第244号，1957年7月2日 受理
1957年 5月日本水産学会中国四国支部例会（福山）で一部発表

れる。

筆者は豊田湖に於ける小鮎蕃殖の生態学的研究を今後も継続して行い，吾国の内水面，殊に人工湖の利用に有益な参考資料を提供すると共に，本湖に蕃殖する稚鮎を附近の他の河川にも移殖放流して積極的に鮎の生産増加に役立せ度い

調査研究を実施するに当り，多大の援助を寄せられた山口県当局並びに地元豊田町役場及び俵山河川漁業協同組合の関係者に感謝の意を表し，更に種々の助言と援助を与えられた本所増殖学科石山礼蔵教授及び漁獲調査に協力せられた漁業学科高瀬増男助教授並びに板村貞夫氏に深謝する

結 果

1 豊田湖の概況

木屋川ダムは，山口県の西端に近い俵山温泉附近に源を発し，下流は下関東郊に於いて吉田川となつて瀬戸内海に注ぐ，水量は常時比較的豊富であるが川幅は余り大きくない木屋川に建設されている（第1図B）。即ち，流路延長 43.5 km の木屋川を豊田町大河内に於いてコン

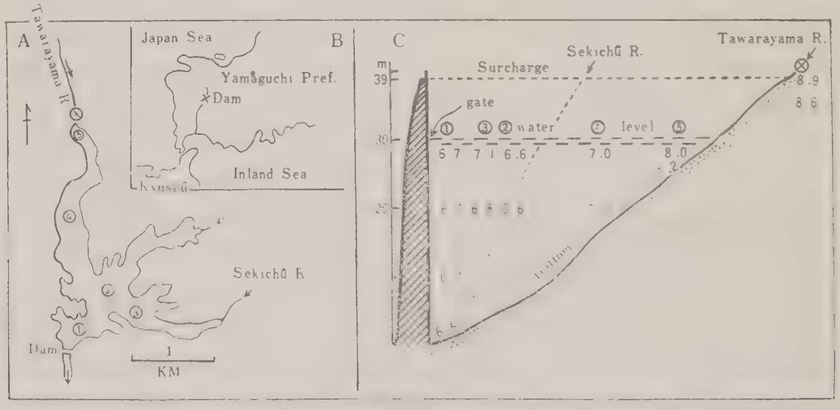

Fig. 1. Showing location of Koyagawa Dam in B, outline of Lake Toyota in A, and section of the Lake in C. Water temperature in Feb. 2, 1957 was observed at five positions in the Lake and the mouth of Tawarayama River, where indicate circle and circle with cross in A and C. Distribution of water temperature at the six positions is given in C.

クリート堰堤で遮断して出来た人工湖である。堰堤及び貯水池の規模概要は下記の如くである。

堰堤高さ：39m（溢流部）；41m（非溢流部），長さ：174.3m，体積：84500m³，集水面積：84.1km²，貯水容量：21,749,600m³，湛水面積：1.606km²，深さ（開扉時）：30m

木屋川ダムは[illegible]，下関市の上水道及び工場用水等を供給する目的で建設された。工事は昭和15年に開始されたが，戦争で一時中断し，竣功したのは昭和30年[illegible]過ぎない。

豊田湖は第1図Aに示す如く湾曲した湖岸に包まれ，上流部に僅かの耕地を残すのみで，外は急峻な傾斜を繞らし，湖岸部には濶葉樹を混えた竹林が多い。

厳冬季と思われる昭和32年2月2日（気温 7.5°C）に於ける湖水水温の分布を5ケ所に於いて観測した結果は第1図Cに示す如くであつた。即ち，湖の上流部は 7～8°C，それより下

流の堰堤に至る広い水域では表面水温 6.6～7.1°Cで，底層は 6.5～7.0°C，堰堤に近い最深部の底層が最低水温を示した。同日，豊田湖に注ぐ俵山川河口附近では 8.6～8.9°C（気温，6.9～7.0°C）で，湖水温よりも稍々高温であつた。更に，同年 8 月27日の盛夏（気温31°C）に於ける水温観測では湖水の全表面は29°C内外を示し，水深 5 m，25.6°C～27.0°・10m，22.9°C～23.0°・15m，20.8°～20.9・20m，17.5° を示し，深度を増すにつれて低下し，最深部25m は11°C を示していた。又同日俵山川の水温は28°C（気温 30°C）で湖水表面より少しく低かつた。従つて水温特性による湖沼標式では[11] 亜熱帯湖の中で人工調節湖の部類に属する。湖水の化学成分，生物相の詳細は追つて発表する。

2 棲息魚類

木屋川の魚類相で特異な点はなく，現在までに知られているのは円口類のスナヤツメを含めて下記の26種である*）。

アユ，メダカ，ナマズ，ギギ，アカザ，ヅナガニゴイ，イトモロコ，カマツカ，ムギツク，モツゴ，ウグイ，アブラハヤ，オイカワ，カワムツ，フナ，コイ，ニゴイ，ドジョウ，シマドジョウ，ウナギ，カジカ，ドンコ，ヨシノボリ，ヤリタナゴ，オヤニラミ。

即ち，吉田川と同じく瀬戸内海西部に注入する佐波川[6] と殆んど同じ様な魚類相である。

3 陸封鮎

a．確認までの経過：木屋川に前記の堰堤が築造される以前は海産鮎が俵山温泉附近まで沂上していた。昭和22年に現在の堰堤から約10km下流に取水堰堤（コンクリート堤の高さ10m）が出来て以来，それより上流には鮎の沂上が全くみられなくなつたので他から稚鮎を数回に亘り移殖放流したがその成績は見るべきものがなかつた。然るに木屋川ダムが竣功した昭和30年の春琵琶湖産小鮎を 1 万尾，更に同31年度には仙崎湾産稚鮎 1 万尾をダムの上流に移殖放流した。ところが31年度は上記放流尾数に比較して，魚体は幾分小さいが著しく多数の鮎が採捕された。それで著者は陸封鮎の蕃殖を推定し，昭和32年度の稚鮎放流は停止することを地元漁業協同組合に勧告し，冬季以来陸封鮎の確認と調査を続行した結果，4 月 9 日に至り漸く小鮎蕃殖を確実に知ることが出来た。

b．小鮎の形態と生態：筆者が豊田湖の最上流部で初めて多数の小鮎を採集したのは 5 月 2 日で，俵山川に稚鮎が沂上をし始めた頃より既に可なりの日数が経過していた。その後 8 月初旬に至るまで同上の水域で数回標本を採集し，それ等の測定結果は次表に示す如くである。

Table 1. Measurements and date of collection of the young *Ayu*, propagated in Lake Toyota. Number of specimens examined is in parentheses.

Date of collection	Body-length, mm (average)	Body-weight, g (average)
May 2, 1957 (7)	43 — 48 (45.5)	0.6 — 1.1 (0.66)
〃 14, 〃 (15)	43 — 47 (43.5)	0.5 — 0.7 (0.63)
〃 31, 〃 (83)	40 — 45 (42.0)	0.5 — 0.7 (0.60)
June 22, 〃 (7)	43 — 47 (46.0)	0.6 — 1.0 (0.76)
August 2, 〃 (8)	50 — 53 (51.0)	1.0 — 1.3 (1.20)

即ち，体長，体重共に普通に知られている小鮎よりも遙かに小形で，而も写真でも判るように著しく痩せている為に頭部が大きく見え，一見した所ではオイカワの稚魚に似た外観を呈し

* 豊田町西市　松田義則氏の採集標本による

Fig. 2. Photograph showing two forms of the young Ayu (*Plecoglossus altivelis*); upper, from upper region of Lake Toyota where the fish propagate; lower, from Saba River where the fish come upstream from the Inland Sea.

ている。この様に瘠せ形の小鮎が大小の群をなして棲息しているのが，豊田湖の最上流部，俵山川の下流附近に認められ，この状態は8月上旬に至るまで続いて見られた。

上記の如く，豊田湖産の小鮎は琵琶湖産のそれに比較して著しく倭小で，約1/2の大きさに過ぎない，いはば超小鮎である。然し，体色素及び鱗の発生，歯系と消化器管の発達程度等を5月2日に採集した標本で調べると所謂「小鮎」として完全に発育している。即ち，5月初旬に採集した個体では，既に体色素[9]は背部及び側線より背方の体側面に可なりよく発生し，特に頭部背面及び鰓蓋部では著しいが，5月14日以後の標本では色素は全体に発達し，胸鰭後方にある本種特有の黄紋が僅かに現われ初めている。鱗の発生状態*）は稚鮎の発育程度をよく示すので[9]特に詳細に調べたが，5月2日の標本では既に全体に発生し，大部分の鱗は circuli を2ケ有し，特に尾鰭の前方では4ケ認められたが頭部の後背側の鱗には circuli は未だ認められる程発達していなかつた。5月中旬の標本では鱗は更によく発達して見られた。歯系[8]の発達程度も鱗と同様に重視す可き形質で，5月2日の標本では既に上下顎の両縁に本魚特有の板状歯が可なりよく発達し，この外に吻端，鋤骨，口蓋骨及び舌骨等に円錐状の歯が生えている。然し，歯骨には未だ数個の稚歯が残存するし，成魚の特徴である舌齒[7]は始めて生じていない。消化管は胃の分化が明瞭に認められ，体長45mmの個体で消化管全長は30mmに達し，松井（1938）[8]の研究によると既に稚魚期を脱し成魚型を示している。幽門垂も多数発生し，胆嚢は明らかで，輸胆管で腸始部に連通している。

以上を要するに豊田湖産小鮎は他の湖沼の陸封小鮎より非常に小形で，海産であればまだシラス期の大きさであるが，魚の諸形態から判断するとその成長段階は立派な小鮎としての成長を示している故に，他の河川への放流種苗として充分役立つことは6月の試験輸送で証明された。唯，上記の様な超小鮎が今春の何時頃から木屋川に浜上し始めたかに就いては未詳であるが，俵山川の各所に於いて，今夏漁獲されている成鮎は幾分小形であるが極めて多数であること及び小鮎の群棲状態から考察すると豊田湖に本年度に発生した小鮎の数量は数十万尾に達し

＊アリザリンレツドで染色し透明標本を作つて精査した。

たのではないかと思われる。

要約及び結語

山口県西端に近い区域を流れる吉田川の上流木屋川に構築された豊田湖に吾国では初めての人工湖に於ける陸封鮎の蕃殖を見た。豊田湖に何故小鮎が発生するに至つたかについての明確な理由はまだ不明で目下継続して研究調査中である。

豊田湖の小鮎は琵琶湖の小鮎に比較して約 1/2 の体長に過ぎない超小鮎である。

然し，鱗，体色素，歯系及び消化器管の発達程度は既に成魚型に近い完全な小鮎の特徴を示している。

豊田湖の小鮎が何故に非常に倭小であるかに就いてはまだ判らないが，豊田湖は陸封鮎の蕃殖に対して水理生物学的に優れた条件を有するものと思われる。

小鮎蕃殖の各種の条件を調査研究して，人工湖の生産増加に資し，且つ蕃殖小鮎の移殖放流による河川の鮎の生産に有力な積極対策の一根拠を作り度い。

終りに，日本各地の人工湖にも小鮎が蕃殖しているか或はその可能性があるかに就いて今後多くの研究者の一層の注意を喚起する。

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合成繊維網糸の摩擦熱の影響について※

深　沢　文　雄

On Relation between Production of Heat by Friction and Durability in Netting Thread

By

Fumio FUKASAWA

Earlier works suggest that the wearing process of netting-threads by friction may be explained in terms of the effect of heat. In synthetic fibers the adhesion mechanism caused by frictional heat is complex, and it is necesary to be explained by considering the effect of heat which is an important factor. In this paper, the effect of heat has been studied, based on the friction between the netting-thread and the low-carbon steel wire (B.S. No.20). The general arrangment of the apparatus to measure the temperature of wire by the thermocouple is shown in Fig. (1).

The heat given out by friction is expended in raising the temperature not only of the wire, but also of the thread. Some heat is lost in the radiation, and then the heat distributed along the surface of contact of the thread with the wire is proportional to the thermal diffusivity, but it is negligible. Hence the total heat of the wire is approximately equal to the heat produced by friction. The thread is driven by a motor at a frictional velocity V and a given normal force P, and its stroke is 10cm. If M is the heat capacity of wire, K the rate of the loss of heat per second and μ the coefficient of friction between the thread and the wire, the heat given out by friction in the wire is $dQ=P\mu Vdt$, and the loss of heat in a time dt is $K(\theta-\theta_0)dt$, when its temerature is raised from the temperature θ_0 of the air to θ. The observations can be represented by the following forms :-

$$(\theta-\theta_0)=Q\{1-\exp(-Kt/M)\}/K \qquad (1)$$

$$(\theta'-\theta_0)=AP^{\alpha} \qquad (2)$$

$$P=C\tau^{\beta} \qquad (3)$$

where A and C are constants. Equations (2) and (3) are the relations among the temperature θ' of thread broken by friction, duration and normal force. The values for $(\theta-\theta_0)$ calculated from (1) are less than the observed values in the first period of sliding. This difference suggests that the coefficient of friction varies with temperature at a given (P, V). The behaviour of μ is represented by the following relation :-

※ 水産講習所研究業績 第245号，1957年7月25日 受理

$$\mu = K(\theta - \theta_0)/PV\{1 - \exp(-Kt/M)\} \qquad (4)$$

In practice, the temperature rises very rapidly at first, and then slowly, approaching the nearly stationary state. From equations (1), (2), and (4) the following expression for μ is derived :-

$$\mu = K(\theta - \theta_0)/PV \text{ or } \mu = BP^{\alpha-1}$$

where B is AK/V. The frictional behaviour of threads used for the experiments is shown in Figures (2), (3), and (4).

緒　　言

従来網糸の耐摩擦性について，網糸と他の物質並に網糸相互間の摩擦現象は多くの人々により色々と研究されている。然しながら現在多く使用されている合成繊維網糸では，繊維を形成する物質は繊維特有のヤング率や伸度を与えるために単なる高分子であるだけでなく複雑なる分子構造と組織とを有しているので，熱に対するその機械的性質は天然繊維である綿糸に比して非常に影響され易い。従つて網糸の耐摩擦性を考える場合には，単に摩擦回数や接触圧力等の要素のみでは不充分であつて上記の要素等により発生する摩擦熱及びそれによる網糸の熱効果の点を考慮することは重要であり且つ興味あることである。

実験方法及び材料

1) 実験に使用した装置は第1図に示す通りである。試料の網糸はモータによつて長さ5糎の範囲を往復運動を行い，相手のライダー型に作られた (B.S. No.20) の極軟鋼線（針金）の凹部との間で摩擦される。針金は長さ4糎でその両端は熱の不良導体にて絶縁され固定してある。往復運動の速度即ち摩擦速度は 10cm/sec, 5.1cm/sec, 3.2cm/sec の三種類に変速出来るようになつている。今，上記のライダー型針金の凹部に網糸の張る角を 2θ とすれば（第1図参照），接触圧力 P は網糸の一端に掛けた荷重が W なるときは，$P = 2W\cos\theta$ となる。接触点の温度は，銅—コンスタンタン熱電対 (0.16ϕ) と反照検流計（感度8.1×10^{-10}A,10.8×10^{-7}V, 周期7SEC）とによつて測定され，この熱電対の一つの接点はライダー型針金の中に埋められ他の接点は[illegible]℃に保[illegible]

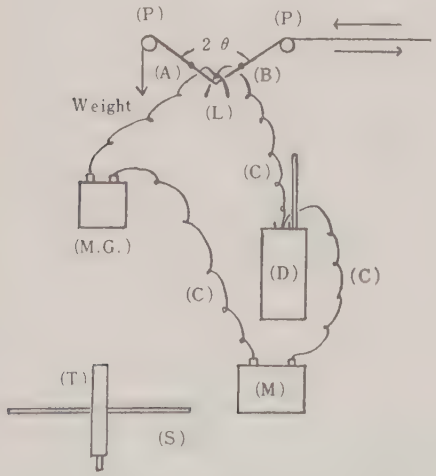

Fig. 1. Schematic diagram of wear tester. (A) (B), Thread; (C), Cu-Constantan thermocouple; (D), Dewer bottle; (L), Low-carbon steel wire;(M), Multiplyer;(M.G.), Mirror galvanometer; (P), Pulley; (S), Scale; (T), Telescope.

2) 本実験に使用した網糸は，見掛上太さの大体同じで且つ同程度の抗張力のものを選びその種類は，アミラン，クレモナ5号(長繊維)，クレモナ万漁（短繊維），サラン，綿糸の五種類であつた。各網糸は第1表に示す性能を有しており，この中の軟化点及び温度の第2次転移点は文献による値である。実験は温度 26～30°C 湿度 78%～84%の条件の下で実施した。

Table 1. Specification of threads used for the experiment.

Kind of material	Number or Deniel	Ply/No. of yarn	Number of the twists per 10 cm of length		Tensile strength Kg	* Softening point °C	* Second-order transition temperature °C
			Upper twists	Lower twists			
Amilan	210 D	3/75	12	23	65.3	210	80
Saran	1000 D	3/54	7.3	7.6	66.5	116—137	70—80
Cremona No.5.	500 D	3/51	10	11	55.0	190—200	70—90
Cremona Manryo	20′S	3/81	9.1	23	62.8	190—200	70—90
Cotton	20′S	3/90	12	29	41.6		

* Taken from reference

実験結果及びその考察

1) 網糸の摩擦熱による温度上昇について網糸と針金との接触点における摩擦による発熱量は，摩擦速度V，網糸と針金との間の摩擦係数μ，接触圧力P等によつて変化する。

今摩擦によつて毎秒発生する熱量Qは網糸並に針金に毎秒供給される熱量で$Q=P\mu V$で表わされる。針金から毎秒失われる熱量はその逃げる割合をKとすれば $K(\theta-\theta_0)$ である。但しθ_0は周囲の温度でθは任意の時間tにおける網糸の温度である。針金の熱容量をMとすれば針金の毎秒の温度上昇は，後述するように網糸に伝わる熱量は小さいので省略すると

$$\{Q-K(\theta-\theta_0)\}/M$$

である。従つてdt時間には

$$d\theta/\{Q-K(\theta-\theta_0)\}=dt/M$$

上式を積分して$t=0$, $(\theta-\theta_0)=0$の条件を入れると

$$(\theta-\theta_0)=\theta\{1-\exp\left(-\frac{K}{M}t\right)\}/K \cdots\cdots\cdots(1)$$

が得られる。比例常数Kは輻射並に伝導によつて毎秒失われる熱量の割合であるから各網糸によつて定まる。次に網糸がある摩擦速度で往復運動を行うのであるから針金との接触点附近の空気は攪乱される。この場合輻射によつて失われる熱量は小さく，Vを変化させてK値を求めて見た時殆んどKは一定であることから空気の攪乱による影響は省略しても差仕えない程度である。更に亦接触点に発生する熱量は，試料の網糸と針金の両者に分配される。その分配される割合は両者の熱伝導率λ，比熱c，密度ρ等に関係する。金属の場合はその温度伝導率$\lambda/c\rho$を考慮すればよいが，網糸ではそれ以外に水分と空気の含有率を考えなくてはならない。従つて，網糸と水分と空気の三者の組合はさつた時の状態を考えるとその熱伝導率λ_0は

$$\lambda_0=\lambda_1(V_1)+\lambda_2(V_2)+\lambda_3(V_3)$$

で示される。λ_1, λ_2, λ_3は夫々繊維，水，空気の熱伝導率でV_1, V_2, V_3は繊維，水，空気の容積比(%)である。上式の空気のλ_3は水のλ_2に比べて$1/12$程度で且つ繊維間の空気胞が微小にして時流を起さず輻射が吸収されるものと考えると，含有する空気の影響は無視出来て上式は

$$\lambda_0=\lambda_1(V_1)+\lambda_2(V_2)$$

となる。吸湿量の影響を考慮すると，網糸の温度伝導率kは

$$k=\lambda_1(V_1)+\lambda_2(V_2)/c_1\rho_1(V_1)+c_2\rho_2(V_2)$$

で表わされる。但しc_1,ρ_1,c_2,ρ_2は繊維及び水の比熱と密度である。c,ρ,λの値を入れて温度

伝導率を計算してみると針金では$k=1.57\times10^{-4}cm^2/sec$，サランでは$k=5.29\times10^{-7}cm^2/sec$である。

相接触している物体間に分配されて伝わる熱量の割合は，各物体の温度伝導率に比例するものとすれば，サランと針金の間の分配比は（1：300）程度となり摩擦による発熱量は殆んど針金に移り，網糸側に流れる熱量は省略しても差仕えない。他のアミランでは（1：180）クレモナでは（1：190），綿糸が（1：280)程度であるからサランの場合と同様に取扱える。

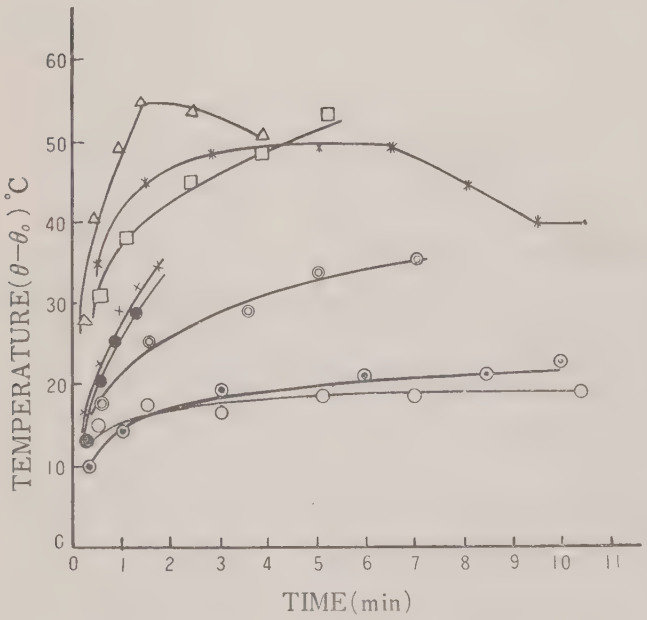

Fig. 2. Relation between temperature (observed values) of the thread given out by friction and sliding time. ○, Amilan P=1.8 Kg; ◉, Cotton P=1.8 Kg; ◎, Cremona No. 5 P=1.8 Kg; ●, Saran P=1.8 Kg; ×, Cremona Manryo P=1.8 Kg; □, Cremona No. 5 P=2.7 Kg; ＊, Amilan P=2.7 Kg; △, Amilan P=2.7 kg.

従つて針金の温度を測定することにより網糸の温度を知ることが出来る。実際に第1図の装置で測定してみると温度と時間との関係は第2図で示すようになる。その実験式を求めてみると

$$(\theta-\theta_0)=a\{1-\exp(-bt)\}\cdots\cdots(1)'$$

が得られる。ここで(1)と(1)′を比較してみると

$$a=Q/K=\mu PV/K$$
$$b=K/M$$

である。然し乍ら，$(\theta-\theta_0)$の測定値と(1)′式よりの算出値とを比較してみると各網糸とも，tが短い期間ではPが大なるに従つて測定値の方が大きい値を示している。Pが小さくなるにつれて，その差の次第に小さくなり(1)′式の値に近付いてくる。時間に対する温度の変化は一般に，最初は急激に上昇し次第に緩かになり始んど定常状態に近付くことが申しアミランが最も緩やかで，次いで綿糸でサラン，クレモナの順である。アミランは破断直前に温度が下る傾向がある。これは他の網糸に比べて破断が緩やかに起るので，接触面積の減少によるものと考えられる。本実験で第1表に示した性質を有する網糸では，破断時の温度は同一の(P,V)の条件ではクレモナ5号が最高でクレモナ万魚，サラン，アミラン，綿糸の順で低くなつた。このことは各網糸の摩擦係数μの大小及びその性質によるものでμについては(4)で述べる。

2) 破断時の温度と接触圧力との関係

網糸の摩擦個所の破断時の温度θ'と接触圧力Pとは実験の結果第3図から次の実験式が得られる。

$$(\theta'-\theta_0)=AP^{\alpha}\qquad 0<\alpha<1\cdots\cdots(2)$$

但し$V=10$cm/secである。Aは比例常数である。

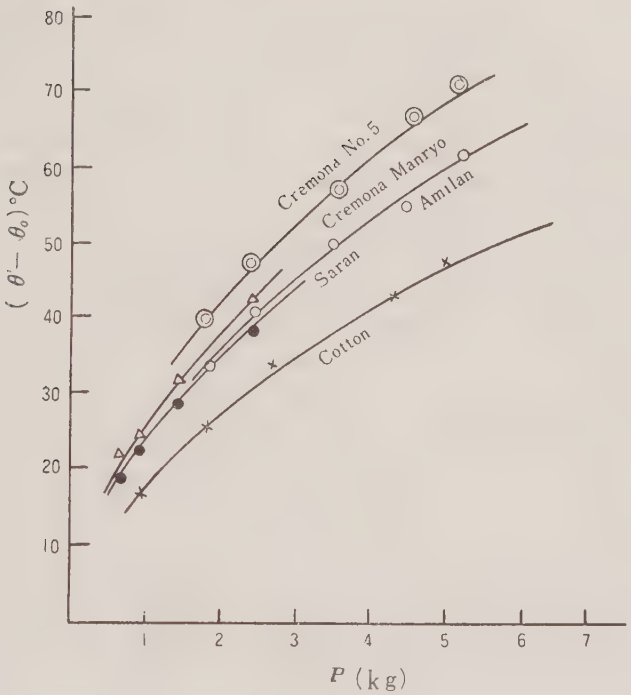

Fig. 3. Relation between temperature θ' of the thread broken by friction and normal force P.

A, αの値は第2表に示す通りである。

Table 2. Values of constants in equation (1),(2),(3).

Kind of material	α	$\alpha-1$	$A\times10^{-3}$ °C/dyne	B	β	$C\times10^{7}$ Dyne/sec	$K\times10^{-3}$ Cal/°C.sec
Amilan	0.558	−0.442	11.2	15.5	−0.283	1.62	0.330
Saran	0.545	−0.456	13.5	12.4	−0.400	1.01	0.219
Cremona No.5	0.543	−0.464	17.6	19.8	−0.419	3.06	0.268
Cremona Manryo	0.536	−0.457	14.8	15.9	−0.618	3.04	0.256
Cotton	0.588	−0.412	5.58	3.33	−0.483	2.99	0.143

3) 接触圧力Pと破断時間τについて

Pとτとの関係は，$V=10$cm/secなる場合第4図に示すような曲線として表わされる。即ち

$$P=c\tau^{\beta} \qquad \beta<0 \quad \cdots\cdots(3)$$

Cは比例常数であつて，本実験の試料ではC，βの値は第二表に示す通りである。

各網糸の破断時間τを見ると長繊維の合成繊維の網糸では，τが急激に減少し始める附近の（P，θ）で耐熱性の特色を良く表わしている。アミランでは（$P=3.6$kg，$\theta'=80.7$°C）の附近からτは急激に減少する。このことは多くの研究者によつて報告されているように，アミランの伸度は温度の上昇と共に増加し温度の第2次転移点θ_sである80°C附近までは僅かに上昇しているだけであるが，それ以上の温度になると急激に伸度は増加し破断に到る性質によく

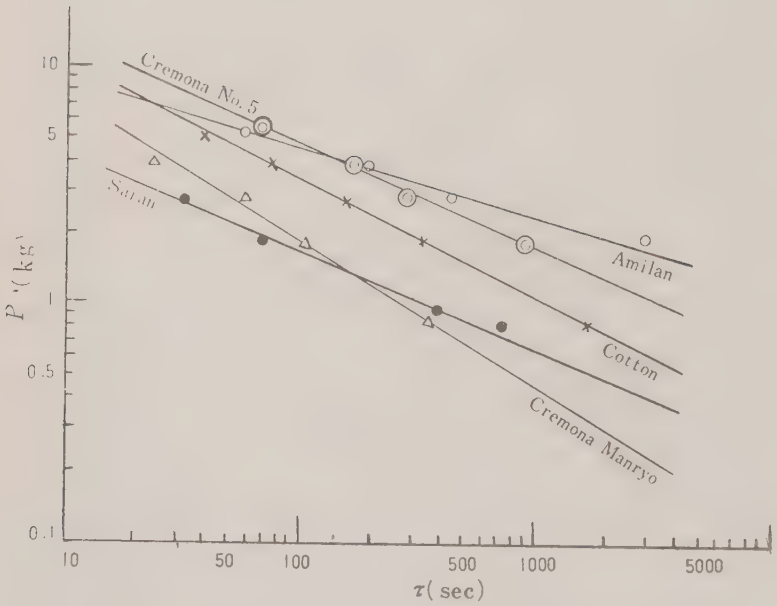

Fig. 4. Relation between normal force P and duration τ of the thread.

合致する。同様にクレモナ5号は（P=3.6kg, θ'=87.2°C）でτが減少するのはθ_S=90～100°Cであることから了解出来る。クレモナ万漁も同じクレモナでも（P=1.8kg, θ'=66.3°C）でτ=100.3secとなり，クレモナ5号に対してτが$\frac{1}{15}$程度であるのはクレモナ万漁は短繊維（長繊維のクレモナ5号とは製法が多少異なる）であるため熱的の影響より摩耗による影響の方が大であるからである。

サランは（P=1.8kg, θ'=64.1°C）でτ=76.9secでこの辺りからτは急激に減少する。サランのθ_Sは80～70°Cであるにもかかわらずθ_S以下でτが減少し始めるのは，サランは熱的性質において他の繊維より劣つているためで文献によればサランの引張伸度は40～50°Cで40～50%に達している。

従つて，重要なことは各網糸の第2次転移点に達する条件が問題となる由であるから（P, μ, V）について考えてみると，μは各網糸について一定と考えられるが実際はμは温度の函数であり換言すればP及びVの函数であり温度が上昇すればμは小さくなる性質を有している。その詳細は（4）に述べる。P及びVが大になると短時間でθ_Sに達し耐久時間は小になり破断に到る。即ち各網糸の耐久性は第2次転移点を界として急激に悪化する。第三表は綿糸

Table 3. Relation between $\tau'$and W/T of threads. T, Tensile strength; T', $T/T_{(Cotton)}$; τ', Duration rate τ/τ (Cotton).

Kind of material	T	T'	Weight W=1Kg		Weight W=1.5Kg		Weight W=2.5Kg	
	Kg		W/T	τ'	W/T	τ'	W/T	τ'
Amilan	65.3	1.56	0.0153	8.91	0.0229	2.88	0.0382	2.41
Cremona No.5	55.0	1.32	0.0182	2.64	0.0273	2.11	0.0455	2.36
Cremona Manryo	62.8	1.50	0.0159	0.373	0.0238	0.381	0.0397	
Saran	66.5	1.61	0.0150	0.227	0.0228	0.135	0.0375	
Cotton	41.6	1.00	0.0240	1.00	0.0360	1.00	0.0600	1.00

の抗張力及び破断時間を単位にとつて，他の各網糸の抗張力と破断時間を表わしたものであ

る。V(=10cm/sec) を一定にしてPを変えた時，アミランではPが小で 0.9kg (W=0.5kg) 以下では$\theta' < \theta_S$で，破断時間が綿糸に比べて遙かに長く20倍以上にもなるが，Pが大となつて$\theta' > \theta_S$となると破断時間は短くなり綿糸との比τ'は1に近付いてくる。クレモナ5号もアミランと同じ傾向の性質を示すが低荷重ではアミラン程綿糸に対して破断時間τは大でないがPが大きるに従つてτの減少がアミランより緩かである。サラン，クレモナ万漁は綿糸に比べて摩擦に対しては全く弱いが，サランとクレモナ万漁では低荷重においてはサラン高荷重においてはクレモナ万漁の方がτが大きい性質を有している。然し以上述べたτの比較は試料の網糸が全く同一の条件を有していないから厳密には定量的に綿糸に対して何倍の耐久力があると言えないが近似的には第三表の数値（実験値）は妥当性を有している。例えば抗張力においてクレモナ5号及びアミランは綿糸の1.3～1.5倍でありそのτの比はそれ以上であるから綿糸の方が耐摩擦性は劣つている。

Pが大になるとτ'が1に近付きτ'が1.3～1.5以下になつて綿糸の方が抗張力の割合には耐摩擦性が大であると言うことが出来る。

サラン，クレモナ万漁は抗張力においては綿糸の1.5～1.6倍でありながらPの大小にかかわらず常に綿糸のτに比べて小さくその耐摩擦性は綿糸に劣つている。

4）摩擦係数μについて

1）で述べたtと（$\theta - \theta_0$）の関係において，摩擦の初期の（$\theta - \theta_0$）が（1）′式より求めた値が測定値より小さい原因を考えてみると，Vを一定にしてPを大にすることは（$\theta - \theta_0$）が大になることである。亦各網糸とも大体t＝2分前後で定常状態に近付くことが測定される。定常状態になることは

$$Q = K(\theta - \theta_0) \quad \text{或は} \quad P\mu V = K(\theta - \theta_0)$$

であつて上式は（1）のt→∞とおいた場合である。そこでKとμは各網糸毎に一定の値を有するものと考えられる。所が（$\theta - \theta_0$）の測定値と（1）′式よりの算出値の方が大でその差はPが大なる程大となるが，このことはμが温度の函数であり，温度は一定の（P, V）では時間と共に変化するから（1）より

$$\mu = K(\theta - \theta_0)/PV\{1 - \exp(-\frac{K}{M}t)\}$$

で表わされる。破断時の P, θ', τ, μの間には（1），（2）式より

$$\mu = KAP^{\alpha-1}/V\{1 - \exp(-\frac{K}{M}\tau)\}$$

或は

$$\mu = BP^{\alpha-1}/\{1 - \exp(-\frac{K}{M}\tau)\}$$

なる関係がある。

定常状態になればμも一定の値を示すからその場合は

$$\mu = K(\theta - \theta_0)/PV$$

特に破断の場合には上式と（2）より

$$\mu = BP^{\alpha-1} \qquad \alpha - 1 < O \qquad B = AK/V$$

で表わされる。以上述べたようにμは温度と共に変ることは，その表面状態が温度により変化するからである。更に撚数による表面状態の異りに対するμの変化を調べてみると，網糸をストランドの状態にして摩擦実験を行う時その温度は撚糸の場合と大差なく，その差は2°C前後で，殆んど撚数の影響はないことが判る。

5）K値の計算

摩擦実験において毎秒失われる熱量の割合であるKは，前述の（1）′式から求めることが出来る。各網糸は夫々熱伝導率，比熱，密度等が異るから同一条件の（P，V）で計算してみれば当然異つてくる。その結果は第二表に示す値をとる。即ちアミラン，クレモナ5号，クレモナ万漁，サラン，綿糸の順序でこの大きさの順は丁度摩擦熱が網糸と針金とに分配される比率の順序に一致している。各網糸のKの値を平均してみると$K=0.243\times10^{-3}\mathrm{cal/°C\ sec}$である。

Kを求める他の方法として摩擦の初期において摩擦の仕事量から

$$\mu PVt \fallingdotseq (\theta-\theta_0)MJ$$

J：熱の仕事当量

が得られ，上式からKを求めることが出来る。第2表をみるとKの値は綿糸が他の網糸に比べて小さいが，これは綿糸は短繊維であるから摩擦中に摩耗された繊維が針金の周囲に附着して保温の役目をするからと考えられる。

要　　約

1）従来の網糸の摩擦試験では，摩擦回数，接触圧力等の影響から網糸の衰退を取扱つているが複雑な熱的性質を有する合成繊維網糸では上記の要素により発生する摩擦熱の熱効果を考えるべきであるから本実験ではこの摩擦熱を測定し網糸の衰退と摩擦熱との関係を調べてみた。

2）合成繊維網糸では第二次転移点を境界として，摩擦熱による影響が急激に変化する。

3）摩擦熱は（P，μ，V）によるから，P，Vが一定ならばμが問題となる。μは一定でなく温度の函数であり換言すればP及びVの函数でもある。特に定常状態になれば破断時の時には$\mu=BP^{\alpha-1}$（V一定）で表わされる。

又網糸のような弾性的物質では幾何学的な表面状態の変化（例えば撚数による変化）はPが非常に小さい時でない限り余りμには関係しない。

4）破断時間による耐摩擦性はアミラン，クレモナ5号は低荷重では綿糸より遙るかに優秀であるが高荷重では綿糸の方が優秀である。サラン，クレモナ万漁は荷重の大小にかかわらず綿糸より劣る。破断時間と接触圧力との関係は（3）式で表わされる。

5）摩擦速度Vを変化させた時の（P，θ）の関係はアミランでは

$V=10\mathrm{cm/sec}\cdots\alpha=0.558$　　$V=5.1\mathrm{cm/sec}\cdots\alpha=0.552$　　$V=3.2\mathrm{cm/sec}\cdots\alpha=0.544$

でVが極端に変化しない限りαは殆んど一定と見做しても差支えない。Kについても同様である。

終りに御指導を賜わった本校の[illegible]教授並に[illegible]御便宜を計わった日本漁網下関工場試験室の長田，中村両氏に厚く感謝する。

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STUDIES ON THE RAJID FISHES (Rajidae) FOUND IN THE WATERS AROUND JAPAN※

By

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(With 3 Plates and 86 Text-figures)

1958

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I. Introduction

The fish referred to the family Rajidae, a well-known natural group in batoids are found in nearly all the seas of the world, especially in the temperate and arctic regions.

General revisional studies of the fish and the relatives have been made by various authorities, viz., MÜLLER and HENLE (1837—1841), DUMÉRIL (1852, 1870), GÜNTHER (1860), HASSE (1878—1885) and GARMAN (1913). A series of painstaking works were written about the fish by CLARK (1926), WHITE (1937) and BIGELOW and SCHROEDER (1934—1953) published much more extensive studies in the fish, which have been acknowledged as giving a basis for the taxonomy of rajids and other batoids found especially in the Atlantic basin. Great progress has recently been made in the taxonomy of many teleosts. Indeed there are several accounts which treat of the discrimination of some common rajids, but Japanese rajids have remained neglected, so far as taxonomy is concerned, for the records concerning the fish, not to speak of other groups of Chondrichthyes, seem incomplete and unsatisfactory to the author. This is why the author has made the present investigation under the supervision of Dr. K. MATSUBARA with a view to obtaining a sounder basis for the taxonomy of this neglected group of fish.

In order to show a more precise method of distinguishing Japanese rajids into genera, species and subspecies, and clarify interrelationship in the family and their genealogical relation to batoids, the author has examined the fish in the following characters, both external and internal, which seem valid to some extent in systematizing the fish: external reproductive organs in both sexes, such as clasper and egg-capsules; snout; tail and its electric organ; placoid scales and their derivatives; vertebral counts; numbers of valves in the heart and the intestine; color and pattern of the integument.

Many elasmobranchs have simpler external features than teleosts, but it is very difficult for us to distinguish species of rajids from one another, especially in their earlier stages, when they remarkably resemble one another in general appearances. Most elasmobranchs in their earliest self-supporting stage are larger in size, as compared with teleosts, and their bodily parts vary a great deal in proportion to their growth. Besides, some pronounced sexual dimorphism presents itself in most rajids. Consequently, these make it difficult for us to identify any particular species of the fish, if we are not provided with minute accounts of the fish characters, such as meristic and dimensional measures, in various stages of the fish.

Fortunately the author has succeeded in obtaining twice as many species as were known to ichthyologist till the time of this investigation of his. The following list represents all the rajids dealt with in the present investigation, including three genera, twenty-one species and four subspecies, some of which will serve for emendation or contribute new information to the science of ichthyology.

In describing the species in the text, the author has used for brevity's sake the Roman alphabet of gothic type ranging from **A** to **W** as the substitutes for their scientific names, and these names belong to the southern form or the northern form, two major groups of species. Some are included in the genus *Raja* of the southern form and others in the genera *Breviraja* and *Rhinoraja* of the northern form, the genera *Raja* and *Breviraja* containing several newly-established subgenera.

Genus *Breviraja* BIGELOW and SCHROEDER, emend

	Abbreviations*)
Subgenus *Notoraja*, n. subg.	
B. tobitukai (HIYAMA)	A
Subgenus *Bathyraja*, n. subg.	
B. isotrachys (GÜNTHER)	B
B. trachouros, n. sp.	C
B. abasiriensis ISHIYAMA	D
B. diplotaenia ISHIYAMA	E
B. matsubarai ISHIYAMA	F
B. aleutica (GILBERT)	G
Subgenus *Arctoraja*, n. subg.	
B. parmifera (BEAN)	H
B. smirnovi smirnovi (SOLDATOV et PAVLENKO)	I
B. smirnovi ankasube, n. subsp.	I′
Genus *Rhinoraja* ISHIYAMA, emend	
Rh. odai, n. sp.	J
Rh. kujiensis (TANAKA)	K
Rh. longicauda ISHIYAMA	L
Genus *Raja* LINNAEUS, emend	
Subgenus *Okamėjei*, n. subg.	
R. kenojei MÜLLER et HENLE	M
R. acutispina, n. sp.	N
R. hollandi JORDAN et RICHARDSON	O
R. macrophthalma, n. sp.	P
R. porosa meerdervoorti GÜNTHER	Q
R. porosa tobae TANAKA	Q′
R. fusca GARMAN	R
R. schmidti, n. sp.	S
Subgenus *Tengujei*, n. subg.	
R. tengu JORDAN et FOWLER	T
R. pulchra LIU	U
R. macrocauda ISHIYAMA	V
R. gigas, n. sp.	W

On the present treatise, as mentioned above, the main purpose is to provide the reader with the criteria of genera and species or subspecies as well as their relationships, and also provide with the author's conclusion as to the validity of the characteristics that have been examined in this investigation. Although racial or population study is of economic importance from a viewpoint of fishery biology, the author wishes to defer future works on minor biological units below subspecies.

However, since nothing is known about concise method for age-determination in any particular species among cartilaginous fishes, a method which functions possible to determine the age of some rajids was first developed by the present author and is amended in the present study.

* These abbreviations are referred to those given in the preceding paper on egg-capsules (ISHIYAMA, 1958).

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III. Materials and Methods

Rather extensive collection of the rajid fishes and their relatives have been done to be used in the present study. The following table indicates those localities, data of collection and number of the specimens used, which were principally gathered in the landings captured by the motor trawlers operating in the seas covering from the south China Sea to the Sea of Okhotsk.

Deposition of the specimens:- The specimens used in the present investigation were arranged in the three sets, taken from various localities as aforementioned,

involving both the younger and the older fishes and egg-capsules of all the members of known and newly described species, except for *Breviraja parmifera* (BEAN), which was collected only one adult male by Dr. K. MATSUBARA from off Muroran in Hokkaido, and the egg-capsules of *Breviraja abasiriensis* and *B. smirnovi ankasube*. Of these three, a set of the specimens including holo- and paratypes of the newly described species together with those hitherto known ones are preserved in the Department of Fisheries, Faculty of Agriculture, Kyoto University, and the other two are preserved in the Museum of Comparative Zoology of Harvard University and in the Zoological Laboratory of the Shimonoseki College of Fisheries, respectively.

Measurements, counts and terminology:- The methods of counts and measurements as well as the terminology of various organs used in this work are followed with illustrations and explanations given by CLARK (1926) and BIGELOW and SCHROEDER (1953) as given in the next lines:

1. All the measurements and counts were taken from the specimens preserved in the formalin (ca. 10%).

2. The observation on the color and pattern of the integument was done in both fresh and preserved specimens.

3. For the histological study of some organs the formalin preserved specimens were used and cut in sections by usual methods.

4. The measurements of the bodily parts were given as follows:

(1). The total length was measured from the tip of the snout to distal tip of the tail.

(2). The disc-length was represented by the vertical length from the tip of the snout to the middle between posterior extremities of the pectorals.

(3). The disc-width is horizontal distance between the two lateral angles of the pectoral fins.

(4). The length of tail was measured from the center of the cloaca to the tip of the tail, which is subdivided at the insertion of the 1st dorsal fin into two parts, the pre- and procaudal.

(5). The term of head-length was meant the distance from the tip of the snout to the center of 5th gill slits of the two sides.

(6). The diameter of eye was indicated by longer axis of the eye-ball inclusive of the integument.

(7). The interorbital width is the least horizontal distance between the two inner dorsal ridges of the orbits.

(8). To indicate the degree of notch in the pelvic fin, the distance from the tip of anterior lobe to incised corner between the two lobes was measured and termed it ventral incision.

(9). The length of the clasper was represented by the distance from the distal tip to a point of emergence from the skin on inner lateral side of the tail.

(10). To indicate the characteristics of the cranium in each form satisfactorily, the details were given in Fig. 26.

(11). The vertebral counts were enumerated by the X-ray photographs or by dissections.

5. To show relative growth of the bodily parts the writer has taken the disc-width as the standard dimension substituted for the absolute growth length.

6. In some characters, the biometric study was adopted so as to indicate critical

Table 1. Localities, number of specimens captured of each form and other data related to the collection and examination of the samples. For abbreviations other than followings, see page 2 in the text; E, the East China Sea and the Yellow Sea; In, the Inland Sea; J, the Sea of Japan; O, the Sea of Okhotsk; P, the Pacific; + indicates the occurrance of the species recognized. Other details on the materials examined in the respective scheme will be mentioned later on.

No.	Locality, etc.	Species	A	B	C	D	E	F	G	H	I	I′	J	K	L	M	N	O	P	Q	Q′	R	S	T	U	V	W
	Number of specimens		22	34	30	10	31	18	17	1	21	25	17	27	27	102	68	59	72	13	60	67	40	51	89	37	21
	〃 〃 egg-capsules		4	4	5		5	2	12	2	4		2	6	2	10	6	32	2	2	16	4	4	2	25	7	2
1	Wakkanai, Hokkaido,	O		–							4														15		
2	Esashi, 〃 ,	O																							3		
3	Monbetsu, 〃 ,	O		9		1			2		17														+		
4	Abashiri, 〃 ,	O				9																			–		
5	Otaru, 〃 ,	J																						+	+		
6	Kushiro, 〃 ,	P		3			12	16	9					2	2										4		
7	Muroran, 〃 ,	P		3	10		9	+	4	1				–								2					
8	Hachinohe, Aomori,	P		3	13		–	2						10	10	+								2	29		
9	Funakawa, Akita,	J		10								2				14				3							
10	Shiogama, Miyagi,	P		+	7		8		2					13	13							1					
11	Chôshi, Chiba,	P					2							2	2	4			+	+	64				2		
12	Yokosuka, Kanagawa,	P														+											
13	Sado, Niigata,	J		–								4				+					+						
14	Niigata, 〃 ,	J										1				2	1			3							
15	Kanaiwa, Ishikawa,	J														3	3				5						
16	Tsuruga, Fukui,	J														2	20				12			+	+		
17	Obama, 〃 ,	J										16				3	11				16				1		
18	Maizuru, Kyoto,	J		3												3	1			4	+				2		
19	Tsuiyama, Hyogo,	J														7				3	7			21	29		
20	Kasumi, 〃 ,	J														4			8								5
21	Maisaka, Shizuoka,	P	5										17			+			13				11	2	+	23	9
22	Miya, Aichi,	P	15													2								+	2	2	
23	Owase, Mie,	P	2																						+		
24	Oki, Shimane,	J		3								2													2		
25	Senzaki, Yamaguchi,	J														45	20	3	11	–	5						
26	Shimonoseki, 〃 , J, E,	In														13	12	56	28		12			+	6		
27	Mimase, Kôchi,	P																	12		+			6		1	+
28	Yawatahama, Ehime,	P																			3		14				
29	Onomichi, Hiroshima,	In																			+						
30	Totoro, Miyazaki,	P																					15	20	9	5	
	Range of depth captured (ca. m)		300 400	90 230	500 700	80 100	300 500	800 1000	300 700	?	100 200	150 400	330 350	600 800	300 600	20 80	50 90	70 90	80 90	70 100	30 80	20 50	20 50	100 150	50 100	300 400	300 400

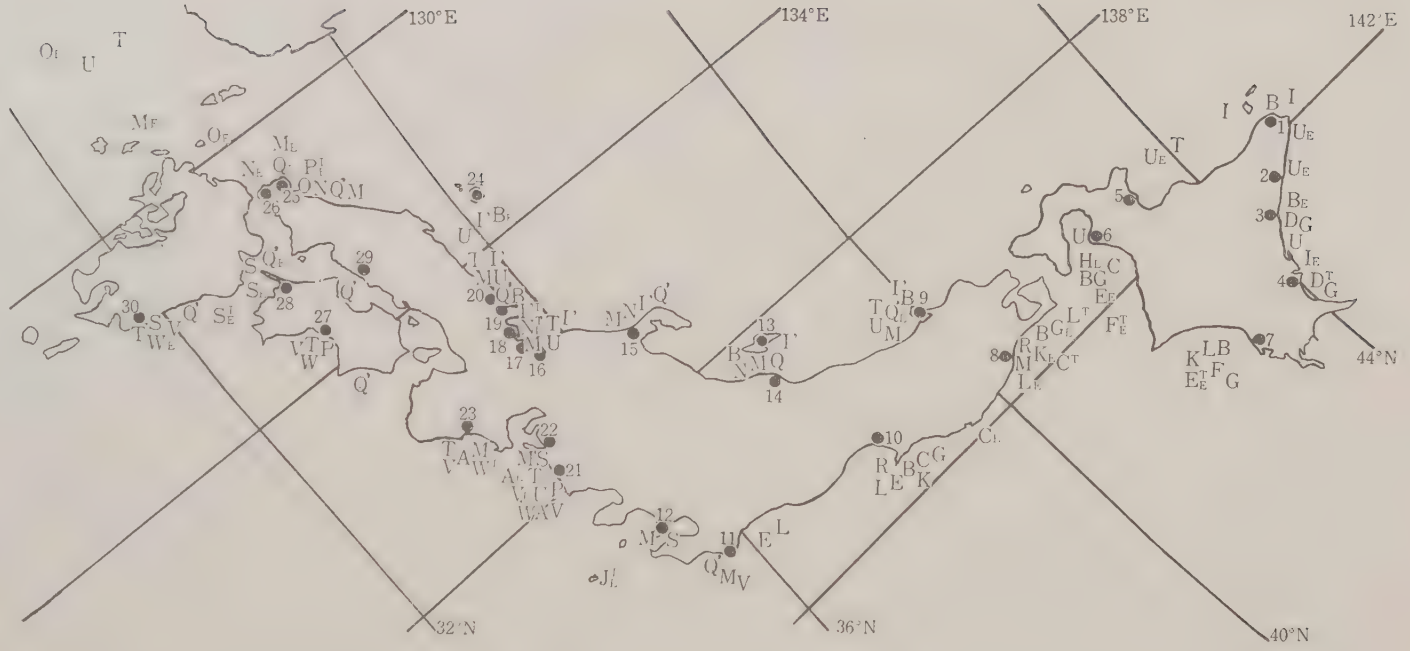

Fig. 1. Distribution of rajid fishes collected during the present study: type localities of species are indicated by T attached to the species symbol; localities of parent fishes with egg-capsules are shown by E attached to the symbol; number given in place of each locality is referred to that in Table 1. For other abbreviations, see p. 2.

basis for the identification or discrimination of the form.*)

Procedure and arrangement of description in general:- With regard to the general part in the present account, the characteristics found in the male organ are offered to provide a fundamental basis on which the phylogenetic classification of Japanese rajids is first developed. Because the single character may not be so reliable as the multiple ones to be used in the taxonomic work such eight characters as mentioned on page 1 which are thought to be important for the present investigation are used together with geographical and other characters. Thus, the present writer has made a comparison of the results obtained from the male organs with those of other characters which are in diversification in greater or less extent.

In the systematic part, the diagnosis in each form is given in the same manner as those given in the previous reports (ISHIYAMA, 1952, '55), viz., the description shall be arranged in order from external to internal and to other characters of the species. As regards the known species, the diagnosis is given by using as many specimens as possible, but in the newly described ones the description shall be made first by the holotype and followed by the paratypes and other notes.

All the drawings were made by the present author, but the photographs were taken by Mr. Sueo HARADA of our college.

IV. Comparative anatomy

A. The external features of organs related to reproduction

a. Clasper or myxopterygium

1. Description in general

In elasmobranchs internal fertilization takes place. The transfer of sperm in the spermatophores from male to female is done by means of the clasper or myxopterygium, which is a specialized organ in male, and is generally considered to be highly specialized modification derived from the pelvic fin. Some worthy contributions have hitherto been made for the purpose of elucidating fine complex and anatomic details in this organ.

PETRI (1867), JUNGERSEN (1899) and HUBER (1901) carried out comprehensive works on internal and external features of this organ. Further, LEIGH-SHARPE (1920-'26) made an extensive study of external character of the organ in various groups of the Chondrichthyes giving many valuable knowledge of the structure and function of the clasper and its associated apparatus. WHITE (1936) also made an important contribution on osteological characters of the organ taken from various representatives within this group. The classification as well as interrelationship within elasmobranchs has been more or less influenced by these characteristics found in the organ thus investigated.

In the present item, the writer has made a comparative study of the characteristics both external and internal of the organ taken from all the members of the Japanese rajids. So far as the present investigation goes, the differences observed in the clasper manifest not only excellent generic and specific features but also apparent

* For assumption of difference between two closely related forms, a test of mean value of the characters was given by means of t-method under 1% or 5% level of significance, using the following formula: $t = \frac{\bar{x} - \bar{y}}{S\sqrt{\frac{1}{N_X} - \frac{1}{N_Y}}}$, where $\bar{x}$ and $\bar{y}$ are means for two forms, N is number of individuals, and S is standard deviation.

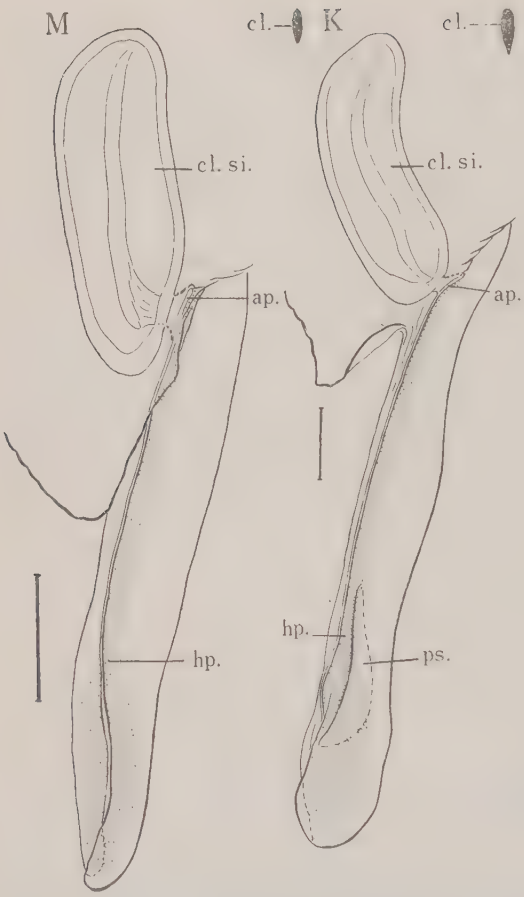

Fig. 2. Dorsal views of two forms in external aspect of clasper and its associated apparatus, based on which the organ was classified into two types, Type-CNE and Type-CSE. ap., apopyle; cl., cloaca; cl. si., clasper siphon analyzed along base of the pelvic fin; hp., hypopyle; K, *Rhinoraja kujiensis*; M, *Raja kenojei*; ps., pseudosiphon; clasper canal is in stippling. Scales indicate 2 cm.

relationship within the group, fully discriminated even between any closely related forms. In fact, the characteristics thus established in the distal portion of the organ are specially noteworthy.

The male organ of the rajid and of other members of the Chondrichthyes in general is composed of two portions, which are distinguished functionally into a bar-like projection, elongated posteriorly from inner lateral side of each ventral fin, the clasper itself in usual meaning, and a large muscular sac, located along the base of clasper, burying each lateral side of the ventral fin, the clasper siphon. These two main apparatus are intercommunicated by the clasper canal or groove, through which the sperm and other reproductive substance pass (Fig. 2).

The clasper is provided with many components in both external and internal structures, nomenclature of which shall be mainly in accordance with those given by LEIGH-SHARPE and other authorities mentioned above. The clasper gland of the rajids, on the other hand, seems to be so similar in the structure throughout all the rajids species dealt here that the organ shall be shown by only short descriptions or figures, if any concern may not show differences between species either in rajids or in related families.

2. Description and comparison of the clasper

(1) External features:

Shape:- From general form in external appearances the clasper may be divided into two types, which are herein called club- and spatula-type, as exhibited in Fig. 2. Club-type is represented by the clasper found in the northern form, in which the organ is usually soft, cylindrical in shape in its main portion and blunt in the glans. Spatula-type can be found in the organ of the southern form, which appears more or less flat, depressed dorso-ventrally and pointed distally.

External structure of the glans clasper*):- The masculinized clasper of the

* Nevertheless the term 'glans clatper' is newly used here with a functional significance, the structure so named in the fish being not morphologically similar to the glans penis in mammalia.

adult male rajid has a highly complicated structure, especially in its glans clasper. Calling his attention to this fact LEIGH-SHARPE (1925 ; p. 567) has claimed that, "the species of this genus fall within well-marked groups, which differs from one another as to their claspers as much, or more than other genera, from RAIA .....", and he classified the fish taken from the Atlantic into nine groups, referring to those names as pseudogenera.

The glans clasper of the rajid is made up of dorsal and ventral lobes, which are tightly clasped together and more or less scrolled with each other, to be capable of opening by inner lateral margin toward dorso-lateral or lateral direction when the organ is erected. Many components, of which characteristics of the organ are made, are asymmetrical in structure between both inner and outer borders of the two lobes of the glans clasper. All these figures and descriptions mentioned in this treatise are made from the organ on the left side, from its dorsal aspect or from its opened out two lobes.

The characteristics in external features of the glans clasper are very different between the northern and southern forms, and are divided into two types and herein called Type-CNE and Type-CSE for brevity's sake.

2. **Type-CNE of the glans clasper:-** The fish with this type of the organ is referred to the northern form, where the glans clasper is composed of the following ten components which are lacking in some species and existing in others: pseudosiphon, slit, ridge, pseudorhipidion, scale, spur, pent, funnel, knife, and claw. Of these, pseudorhipidion, funnel and knife are newly termed here. The first five components mentioned above are found on the outer or inner surface of the dorsal lobe, and the rest are developed on the inner border of the ventral lobe or on the mesial plane between the two lobes.

The finding of the apopyle as well as the hypopyle in all the species dealt with here is noteworthy, but, according to LEIGH-SHARPE, these two passages for the reproductive substances are supposed to be worthless concerning the present investigation.

Pseudosiphon:- The pseudosiphon is well-developed in the six species, **E**, **F**, **G**, **J**, **K** and **L**. (Figs. 2 and 3)

The apparatus is usually a blindly ending sac, wide aperture of which is pointed at both ends, turning latero-outward, from the anterior portion to the midway in the dorsal border of the glans clasper (Figs. 2 and 3; **E**, **F**, **G**, **J**, **K**, **L**). But, the apparatus is very inexplicit in species **B** (Fig. 3 **B**), and is much more ill-defined in species **H** and **I** (**I'**) (Fig. 3 **H**, **I**, **I'**), located on the marginal portion or on the inside border of the dorsal lobe.

From the degree of development and the location of the apparatus in these ten forms, the organ may be assorted into three types, which are herein called Types-Ps^1, -Ps^2, and -Ps^3.

Type-Ps^1 is represented by first six species **E**, **F**, **G**, **J**, **K** and **L**, and the pseudosiphon of this type is broadly developed on the dorsal border of the dorsal lobe. With regard to the degree of development and the location of the apparatus we can recognize some differences in these examples: the pseudosiphon in species **K** (Fig. 2 **K**) is very large, covering the portion from the base to the midway of the elongated glans clasper, but the apparatus is not so much developed in the five species **E**, **F**, **G**, **J** and **L** (Fig. 3) as the preceding species, and the pseudosiphon more or less reduced in size, located on the basal portion of the glans. Type-Ps^2 may be referred to the characteristics found in species **B**, in which the pseudosiphon is developed in a very obscure state, located along the marginal portion of the dorsal

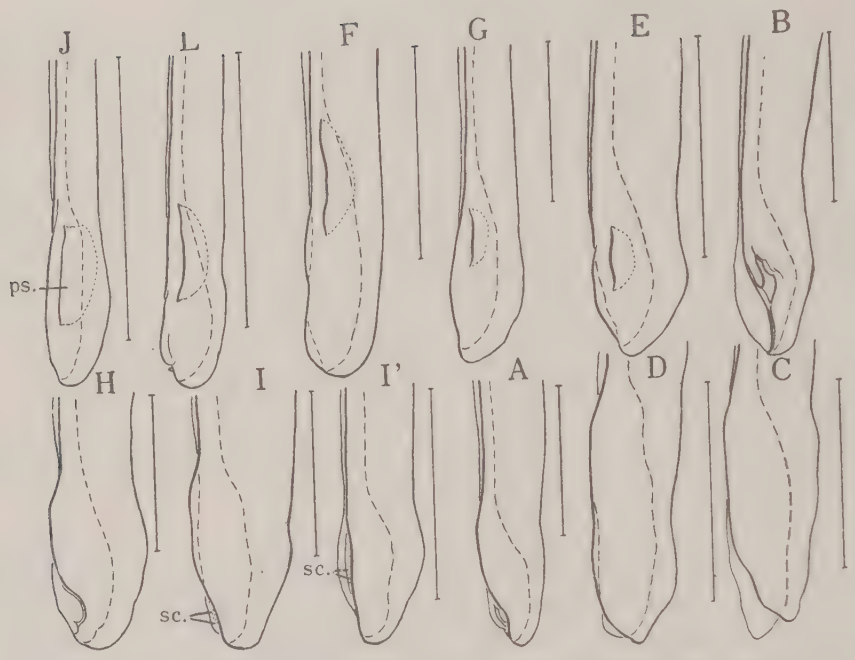

Fig. 3. Dorsal aspects of the glans claspers of twelve forms in Japanese rajids, especially showing differences in the outline of the organ and in the size and location of the pseudosiphon(ps.), based on which three types of the apparatus (Type-Ps^1 to Ps^3) are assorted, and also showing presence and absence of the placoid scales (sc.). Broken line indicates the clasper canal. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia* F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I(I′), *B. smirnovi smirnovi* and *B. smirnovi ankasube*; J, *Rhinoraja odai*; L, *Rh. longicauda*. Scale attached to each figure represents 5 cm, but 2 cm in A.

lobe, where a half vestige of the deep-groove (pseudosiphon proper) is present, separated by a longitudinal process. Type-Ps^3 is exemplified by the two species, **H** and **I** (**I′**), which are characterized by having exceedingly degenerated apparatus, shifted to the inside border of the dorsal lobe and represented as a deep-groove as in the species **B**. Thus, this type is presumably in a more progressed condition than the preceding ones.

Judging from the writers comparison of the pseudosiphon of Japanese rajids in the degree of development and difference of its location, the specialization of the apparatus may have taken place in order from Type-Ps^1 to -Ps^2 and -Ps^3. This hypothetical process in the transformation is sharply seen in the modifications revealed in the dorsal terminals, which are to be explained later on (p. 18).

Slit:- Although the slit is thought to be more or less regularly present along the inside border of the glans clasper of the organ at least in all the Japanese rajids used in the present investigation, it seems very difficult to distinguish it from the pseudosiphon which is also found on the inner surface of the lobe. But, the writer has designated this component as follows: the slit is small, shallow cavity formed by fleshy skin developed on the inner surface of the dorsal lobe, and has no close relation to the dorsal terminal 1. Both number and degree of the development of the component, therefore, seem to have a specific character rather than genealogical

significance as shown in the accompanying Figs. (Figs. 4 and 5).

Ridge:- The ridge is developed in the position near the hypopyle with a distinct elevation on the inner surface of the dorsal lobe. The component is present in three species **B**, **H** and **I** (**I'**), and is supposed to have intimate relation to the degree of development of the pseudosiphon as already mentioned. The ridge is distinct in the species **B** and **H** (Fig. 4 **B**, **H**), but it is less developed in **I** (Fig. 4 **I**). At any rate, such unique development of the component, as seen in these species, is provided with a cartilage referable to the dorsal terminal 2 (cf. Fig. 9).

Pseudorhipidion:- This component is commonly present in the organ of the northern form, and the term is newly alluded in the present study to a structure found on the inner surface of the dorsal lobe. The writer has distinguished the component from the rhipidion termed by LEIGH-SHARPE:- the rhipidion is characteristically developed with porous structure of pitted tissue; but the pseudorhipidion has the smooth skin covering the surface.

The component referable to this character can be discriminated in the groups of species according to the degree of development of the apparatus. The first group, in which the eight species **A**, **C**, **D**, **E**, **F**, **G**, **J** and **K** may be involved, and is abbreviated here as Type-Pr^1. The second, in which the four species, **B**, **H**, **I** (**I'**) and **L**, are involved, reveals in the component less development, and is termed Type-Pr^2. The degree of development of the component varies as that of development of the distal portion of the dorsal marginal, an axial cartilage of the clasper, as will be described later on (cf. Fig. 12).

Scale:- The most interesting fact that has not yet been found either in the European or Japanese rajids is that the minute scales have been found developed on the dorsal border of the ridge in the species **I** and its relative **I'** (Fig. 3). In all other members of the Japanese rajids no such scales were found.

Spur:- The spur, which is regarded as a component that lies on the mesial plane in the glans, can be recognized as a protrusile process from a socket when the organ is erected. The spur is well-developed in the three species **C**, **D** and **F**, but it is illegible in the two examples **B** and **I** (**I'**). The component is absent in the species **A**, **G**, **H**, **J**, **K** and **L**. (Fig. 4). The presence or absence of the spur depends upon the degree of development of the accessory terminal, as is described later on (cf. Fig. 11).

Pent:- The pent is found to exist only in one species **A** (Fig. 4 **A**), and it is provided with a fleshy skin fold attached to the lining of the ventral lobe. The term has been proposed by LEIGH-SHARPE (l. c., p. 23) in naming a component growing on the inner surface of the dorsal lobe of the organ of a sting ray, but the term may be credible to him in view of the fact that the component seems in either case to act as a leading flap of the reproductive substances.

Funnel:- The term 'funnel' is newly alluded to in this study about a component located on the distal portion of the ventral lobe, having a soft projection something like the foot of bivalve mussel. The development of this component is characteristic of some species in the northern forms, but there are marked intraspecific variations in the degree of development of this component. It is distinctively developed in the five species **C**, **D**, **F**, **H** and **K**, but is ill-defined in the three species **E**, **G** and **L**. In other species of the northern members the component is obscure or absent (Fig. 4). The degree of development of the component varies as that of the ventral terminal (cf. Fig. 10).

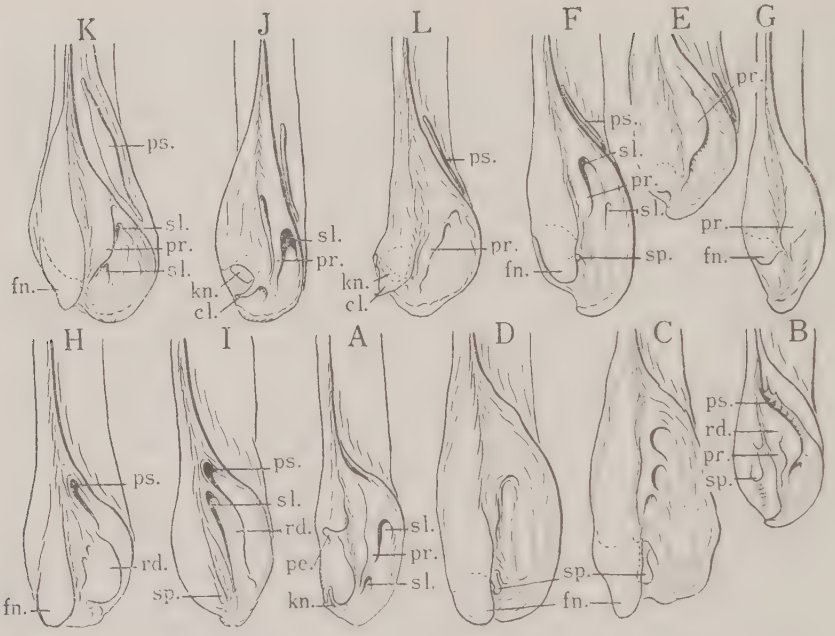

Fig. 4. Showing the arrangement of the structural components developed on inner surface of the glans claspers of eleven forms in Type-CNE of the organ; cl., claw; fn., funnel; kn., knife; pe., pent; ps., pseudosiphon; pr., pseudorhipidion; rd., ridge; sp., spur; sl., slit. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*. Magnification is the same to that in Fig. 3.

Knife:- The knife is also newly termed here in naming a component characteristic of the three species **A**, **J** and **L**, which have in common a remarkable structure in the distal part of the ventral lobe, and the structure is of a fleshy skin under which the 'knife' is hidden protrusibly from a socket. The component is furnished with a knife-blade-like edge turning laterally, and is internally the accessory terminal (kn. in Fig. 4 and cf. Fig. 11).

Claw:- The claw is possessed by the two species **J** and **L**, in which the component is furnished with a process sharply pointed, located in the distal part of the ventral lobe. It is significant that this component, which has been given by LEIGH-SHARPE (1. c., p. 26) to an organ of *Rhinobatus productus*, an European guitarfish, can be seen in these species(cl. in Fig. 4). The component can be considered to be a modification of the accessory terminal (cf. Fig. 11).

ﾒﾒ. **Subordinate division of the northern forms on the basis of the external features of their glans claspers (Typ-CNE)**:- The present analytical comparison of external features of the glans clasper may be said to give the following seven distinct types placed under Type-CNE, viz., Subtypes-CNE$^{1-7}$.

Subtype-CNE^{1} is represented by only one species **K**, the organ of which is regarded to be the annexed characteristics: the pseudosiphon is distinct in having Type-Ps^{1}; the two slits are apparently present; the pseudorhipidion is well-developed as in Type-Pr^{1}, and the funnel is remarkably present, but the other components, such as ridge,

spur, scale, pent, knife and claw are all absent (K in Figs. 2 and 4).

Subtype-CNE^{2} is modeled after the characteristics revealed in the organ of the species J and L, where the pseudosiphon is moderately developed as in Type-Ps^{1}, pseudorhipidion is obscure as in Type-Pr^{2}, knife and claw are present, though ridge, spur, scale and pent are lacking (J and L in Fig. 4). This subtype seems to some extent related with the preceding subtype in having relatively distinct pseudosiphon and less obscure pseudorhipidion, but the present subtype is well-marked from its relatives in having the both knife and claw.

Subtype-CNE^{3} is found in only one species A. The organ is characterized by having slits, pseudorhipidion as in Type-Pr^{1}, funnel, knife and pent, and by lacking in pseudosiphon, ridge, spur and scale. There is an obscure depression along the marginal portion of the dorsal lobe which may be a vestige of the pseudosiphon. This subtype may be linked up in some respects with the preceding one at least in having the knife, but they may be distinguished from each other externally in the presence or absence of the pseudosiphon (A in Fig. 4).

Subtype-CNE^{4} is represented only by the species B, the organ of which may be defined as follows; pseudosiphon is illegible in having Type-Ps^{2}, pseudorhipidion is of Type-Pr^{2}, slit, ridge and spur are present, though scale, knife, funnel and claw are absent (B in Fig. 4).

Subtype-CNE^{5} is exemplified by the two species C and D. The organ in these species is provided with four annexed components, namely two or three slits, pseudorhipidion (as in Type-Pr^{1}), spur and funnel, but it is devoid of the pseudosiphon, scale, pent, knife and claw (C and D in Fig. 4).

Subtype-CNE^{6} has the characteristics found in the organ of the three species E, F and G, which have the following components, pseudosiphon (as in Type-Ps^{1}), one or two slits, pseudorhipidion (as in Type-Pr^{1}), funnel and spur (except for species E and G), but scale, pent, knife, ridge and claw are all absent (E, F and G in Fig, 4).

Subtype-CNE^{7} is represented by the two species H and I (I′), the organ of which is characterized by the presence of pseudosiphon (ill-defined as in Type-Ps^{3}), slit, ridge, pseudorhipidion (as in Type-Pr^{2}) and scale (except for the organ of the species H), but the other components are not at all developed (H and I in Fig. 4).

2. **Type-CSE of the glans clasper**:- The glans clasper of this type is regarded as the organ of the southern form, which is generally furnished with the six annexed components developed only on the inner surface of the glans; slit, rhipidion, spike, sentinel, shield and dike. Last of these, which is newly termed here, is a component which is found rather regularly on the posterior portion of the mesial plane between the two lobes of the glans.

Slit:- The slit is usually well-developed in the organs of all the fishes of this type, although the number as well as the degree of development of the component varies in the species, as is the case with the preceding type. Generally, two large slits are located on the anterior portion of the dorsal lobe. According to LEIGH-SHARPE (l. c., p. 200), this term was first given to a blind ending fissure developed on the inner side of the dorsal surface of the clasper of *Chiloscyllium punctatum*, but the present writer has accounted for the component, fasing his inferences on the structural evidence so as to avoid its confusion with the pseudosiphon mentioned elsewhere (sl. in Figs. 4, 5 and 6).

Rhipidion:- This component is always present in varying degree, composed of

singular structure with pitted, porous tissue, which covers the mesial plane, running rearward from the hypopyle to a midway point of the glans. The rhipidion is monolobed in the seven species (O, Q, S, T, U, V and W), instead of being bilobed in the four species (M, N, P and R). In either case the component is made of the erectile tissue, which is characteristic of the organ of this type (rh. in Figs. 5 and 6).

Spike:- The spike is also usually developed in all the organ of this type, looking like a small or a large projection that lies with the rhipidion. To indicate its degree of development, the writer has assorted the component into three forms which are herein called Type -Sk^{1-3}. Type-Sk^1 is represented by the seven species, N, O, Q (Q′), R, S, T and U, where the spike is more or less obscure, being hardly visible or nearly hidden under the skin or the sentinel. Type-Sk^2 is modeled after the characteristics of the component in the organ of the species P, in which the spike is a long and slender projection, thrusting itself out posteriorly. Type-Sk^3 involves four species, viz., M, R, V and W, in which the component is furnished with rear ends more or less hooked (sk. in Figs. 5 and 6).

The different forms of the spike thus distinguished in its external features are due to the differentiation revealed in the cartilage of the accessory terminal 2, which is to be explained later on (cf. Fig. 16).

Sentinel:- The sentinel is located between the rhipidion and the spike, and varies with species more in this type than in the others.

When the features found in this component are compared, the fish in this category may be classified into five types, which are here abbreviated as Type-St^{1-4} (st. in Figs. 5 and 6).

Type-St^1 involves four species, M, T, V and W, which have each the component elongating posteriorly with or without soft fleshy skin covering the apical portions.

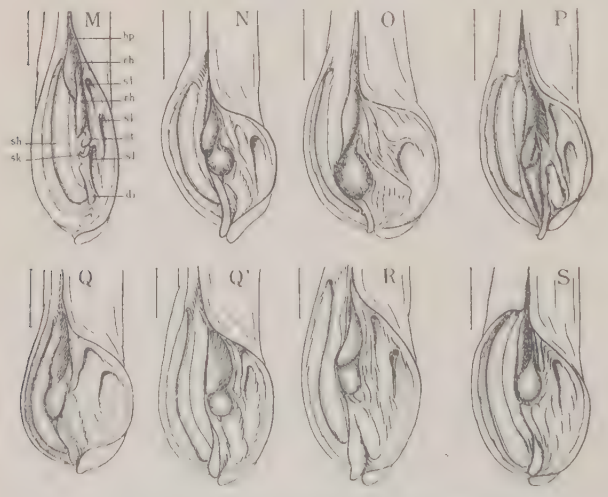

Fig. 5. Showing the arrangement of the structural components developed on inner surface of the glans claspers of eight forms in Type-CSE of the organ; di., dike; hp., hypopyle; rh., rhipidion; sh., shield; sk., spike; sl., slit; st., sentinel. M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q, *R. porosa meerdervoorti*; Q′, *R. porosa tobae*; R, *R. fusca*; S, *R. schmidti*. Scales represent 1 cm.

In the species M, the sentinel appears to be a bulky projection, but it is long and slender in T, whilst in V and W it is short. Type-St^2 is found in the feature revealed by the four species (N, Q, R and S), the component of which assumes a very large size, ensuing posteriorly to the rhipidion, being covered with the soft fleshy skin to be taken as a bulky head. Type-St^3 is found in the two species (O and P); the sentinel is peculiar in these examples, and is distinct from that of the preceding ones, in having the posterior edge with a knife-blade-like margin, which is broadly exposed in the organ of the species P. Type-St^4 has in it only one species U, in which the sentinel is much more remarkable than in the others,

being well-developed into an oval shape, and its lateroposterior edge is furnished with a knife-blade-like structure resembling that found in the organ of European skates, *Raja blanda*, *R. clavata* and *R. rhina* (LEIGH-SHARPE; 1924).

The sentinel is thus specialized into different features, which are conformable internally to the condition in the accessory terminal 1, and is therefore homologous with the spur found in the organ of northern form (Type-CNE).

Shield:- The presence of the shield is characteristic of the organ of this group of the fish (Type-CSE), the component is developed on the inner surface of the ventral lobe. On outside margin of the shield a singular structure with keen edge is present covered with epidermis. The degree of development of the component varies with species, but it seems very difficult to indicate any degree of development of the shield externally as shown in Figs. 5 and 6. Thus, the shield has a very complicated feature as it is closely related internally with the ventral terminal (cf. Fig. 15), which is to be explained later on.

Dike:- The term 'dike' is newly given in the present study to a component found in either distinct or obscure fold covered with fleshy skin, running rearward from basal portion of the sentinel to the symphysis of the two lobes. There are roughly four forms according to the degree of development of the component revealed by the organ of this type (Type-CSE).

The first form which assumes the most prominent feature is developed in the species **N**, **O**, **P**, **Q** (**Q'**), **R** and **S**; the dike reaches posteriorly to, or extends beyond, the symphysis of the two lobes. The second form is represented by the single species **M**; the dike is reduced to a small process, located in the portion far from the symphysis, and reaching the distal edge of the shield. In the third form which involves three species **T**, **V** and **W**; the dike is much more reduced to an ill-defined condition looking like a small ridge, which is connected posteriorly with the extremity of the shield. The fourth form involves only one species **U**, the component of which can hardly be observed externally owing to the enormous development of the

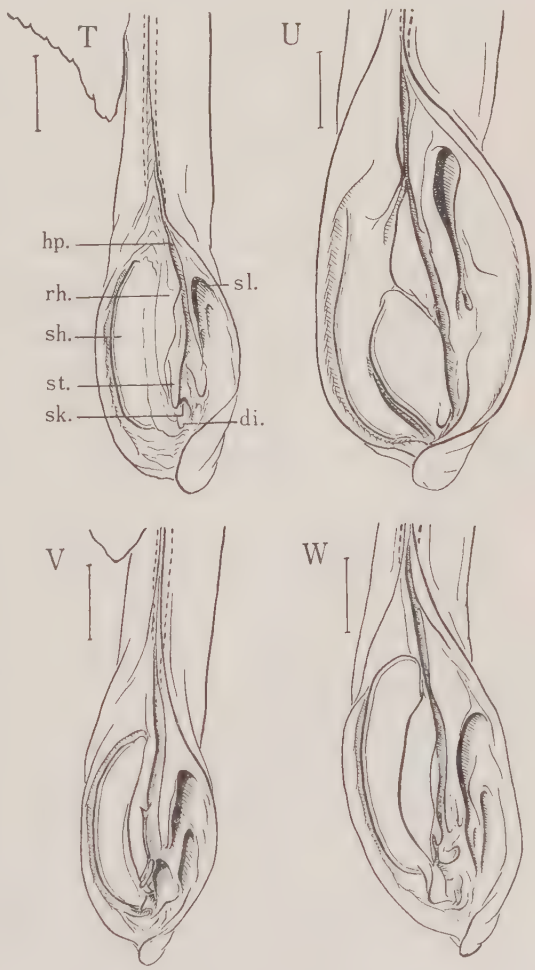

Fig. 6. Showing the arrangement of the structural components developed on inner surface of the glans claspers of four forms in Type-CSE of the organ. T, *R. tengu*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*; other abrreviations attached to the Fig. are the same to that in Fig. 5. Scales represent 2 cm.

shield (di. in Figs. 5 and 6).

In the four forms thus assorted only the process of the ventral terminal is concerned in the degree of development of the dike as it will be mentioned later on (cf. Figs. 17~19).

Subordinate division of the southern forms on the basis of the external features of their glans claspers (Type-CSE):- By a comparative study of the external features of the glans clasper of the southern members thus examined, the writer has arranged them into six subordinate types placed under the main type (Type-CSE) and abbreviated herein as Subtypes-CSE$^{1-6}$.

Subtype-CSE^1 is represented by only one species **M**, whose characteristics of the organ are in possession of the following six components; slits, rhipidion bilobed, spike (as in Type-Sk^3), sentinel (as in Type-St^1), dike with normal shape of second form and shield well-developed (**M** in Fig. 5).

Subtype-CSE^2 is found in the organ of the four species **N**, **Q** (**Q'**), **R** and **S**; these representatives have features in the components very similar the preceding subtype, but the two subtypes are distinguishable in the following points, spike is reduced to as in Type-Sk^1, sentinel is enlarged (as in Type-St^2), and dike is well-developed in the first form, in this subtype. The three components, slits, rhipidion and shield, are also present (**N**, **Q**, **Q'**, **R** and **S** in Fig. 5).

Subtype-CSE^3 is exemplified by the organs of the two species **O** and **P**, whose characteristics in the structure is in the sentinel represented by Type-St^3, in addition to the holding of two slits, dike and shield in usual manner. Besides, the rhipidion monolobed in the species **Q** instead of being bilobed in the species **P**, but the spike is of Type-Sk^2 in the species **P** in contrast with Type-Sk^3 in the species **O** (**O** and **P** in Fig. 5).

Subtype-CSE^4 is found in the organ of the species **T**, in which the following characteristics were noticed; dike obsolete in being third form, three slits are present, spike is in Type-Sk^1, rhipidion is developed in monolobe, sentinel is in slender proje-

Table 2. Comparison of external features of the glans claspers of the Japanese rajid fishes. Abbreviations refer the reader to the text. + and — represent the presence and absence of the component, respectively.

Types	CNE							CSE					
Subtypes	1	2	3	4	5	6	7	1	2	3	4	5	6
Components													
Pseudosiphon	Ps^1	Ps^1	—	Ps^2	—	Ps^1	Ps^3	—					
Slit, number	2	±	2	1									
Ridge	—	—	—	+									
Pseudorhipidion	Pr^1	Pr^2	Pr^1	Pr^2	Pr^1	Pr^1							
Scale	—	—	—	—	—	—	—;+	—	-				
Spur	—	—	—	±	—	—;+	±	—	-				
Pent	—	—	+	—	—	—	—						—
Funnel	—	—;+	—	—	+	—;+	—;+						—
Knife	—	+	+	—	—	—	—	—					
Claw	—	+	—	—	—	—	—	—	—	—	—	—	
Rhipidion	—	—	—	—	—	—	—	+	+	+	+	+	
Spike	—	—	—	—	—	—	—	Sk^3	$Sk^{1:3}$	$Sk^{1:2}$	Sk^1	Sk^1	Sk^3
Sentinel				—	—	—	—	St^1	St^2	St^3	St^1	St^4	St^1
Shield												+	
Dike									+	+	+	+	+
Genus	*Rhinoraja*			*Breviraja*				*Raja*					
Species	K	J;L	A	B	C;D	E;F;G	H;I	M	N;Q;R;S	O;P	T	U	V;W

ction (as in Type-St[1]), and the shield is markedly developed (T in Fig. 6).

Subtype-CSE[5] involves only one species U, whose organ seems to have much specialized features as compared with those of the preceding groups of species or of the forthcoming ones, i.e., sentinel is remarkably developed as represented in Type-St[4], dike is scarcely visible (as in third form), two slits, rhipidion (monolobe), spike (as in Type-Sk[1]) and shield is well-marked in large size (U in Fig. 6).

Subtype-CSE[6] involves the two species V and W, where the spike is marked with a hook-like projection (as in Type-Sk[3]), and three slits, sentinel (as in Type-St[1]), rhipidion monolobed, dike ill-defined (as in third form), and shield enlarged, are all present and characteristics in the organ of the present subtype (V and W in Fig. 6).

The present writer has described and compared external features of the organ of the Japanese rajids, and made the Table 2, which enables any one to distinguish the characteristic feature revealed in the respective representatives.

(2) **Internal features**:

In the present scheme, the writer has made osteological investigation of the claspers in contrast to those characteristics examined externally in the preceding paragraph.

The cartilages of the claspers are composed of many cartilage elements and vary extensively specifically in the rajid fishes, and are largely divided into three groups, viz., basal, axial and terminal ones, which are either the continuation of the basipterygium modified from the cartilages of the pelvic fin or more probably the modification of the radial cartilage of the fin.

The basal group is composed of three elements termed the pelvic basipterygium, the intermediate proximal segment and the so-called β cartilage; the axial group is composed of the axial, the dorsal and the ventral marginal cartilages, and the terminal group is made of many cartilages connected with the constituting terminal elements of the clasper (Fig. 7).

As illustrated in the Fig. 7 marked differences are found to exist in the cartilginous features of clasper between the northern and the southern forms, especially so distinct in the axial and terminal groups of the cartilages that the two groups seem to be much more important for the present investigation. However, those differences are not so conspicuous in the basal group of the cartilages between the two major forms of the Japanese rajids, so that these cartilages are of little use for distinguishing species and groups of species. Moreover, WHITE (1936) proved the fact that the number of proximal segments and other cartilages in the basal group tend to vary,

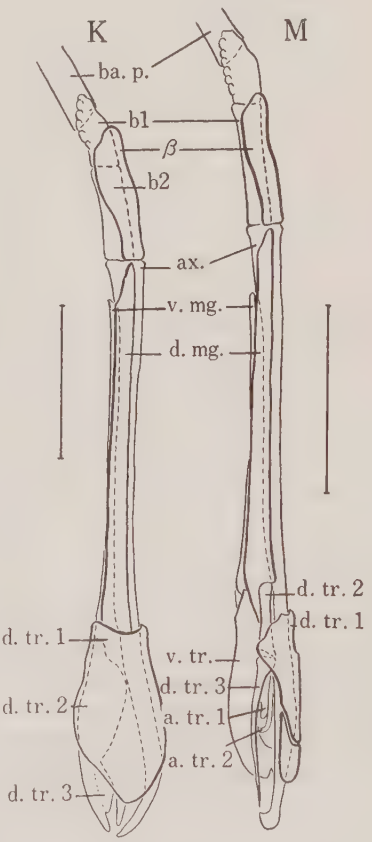

Fig. 7. Dorsal views of two forms in internal structure of the clasper, based on which two types of the organ (Type-CNI and -CSI) were assorted. a. tr. 1—2, accessory terminals; ax., axial cartilage; b^{1-2}, intermediate segments; ba. p., basipterygium; β, beta cartilage; d. mg., dorsal marginal; v. mg, ventral marginal v. tr. ventral terminal. K, *Rhinoraja kujiensis;* M, *Raja kenojei.* Scales represent 2 cm.

being contradistinguishable in the large groups of the elasmobranch fishes. Therefore, the basal group of the cartilages may be used in regard to phyletic consideration of the rajids within allied families of batoids.

Comparing those features of the cartilages in both axial and terminal groups which are present in the glans clasper, the present writer has newly divided the Japanese rajids into two types and called them CNI and CSI in contrast to those respective abbreviations defined in the external features of the organ.

♂. **Type-CNI of the myxopterygial cartilages**:- The clasper with this type of the cartilages is composed of eight or nine elements; axial cartilage (ax.), dorsal and ventral marginals (d. mg. and v. mg.), three dorsal terminals (d. tr. 1,2,3), and one or two accessory terminal (a. tr. 1,2).

Axial cartilage, ax.:- The axial cartilage is a long, round-bar-like element, and is thickened anteriorly and pointed posteriorly. The cartilage is tightly closed together with the dorsal and ventral marginals throughout its nearly whole length, forming the frame of the clasper canal or groove. On the distal part of the cartilage there are many elements (terminal group) which are a frame of the glans clasper in close contact with each other to form a complex structure.

On the basis of the distal part of the axial cartilage three different forms may be found which the writer has called Type-Ax^1, -Ax^2 and -Ax^3. Type-Ax^1 is found in the eight species (**A, B, E, F, G, J, K** and **L**); the axial cartilage is pointed in its distal tip (Figs. 7, 12 and 13). Type-Ax^2 involves two species (**C** and **D**); the element is spatulate distally (Fig. 12). Type-Ax^3 involves two species **H** and **I** (I′); the distal part of the cartilage is truncated (Fig. 13).

Dorsal and ventral marginals, d. mg., v. mg.:- These elements are long, thin cartilages closely attached to either side of the axial cartilage. The dorsal marginal starts anteriorly on the same level, where the axial cartilage is connected with the intermediate segment, but the ventral marginal rises some distance rearward from that level (*vide* Fig. 7). On the other hand, the feature in the posterior portion of the ventral marginal is somewhat instructive. In the posterior elongation of the ventral marginal, are found two distinct forms in the species examined by the writer, i.e., the ventral marginal is much shorter in the posterior portion than the axial cartilage in the seven species of the northern form except the five species (**C, D, J, K** and **L**), in which the ventral marginal projects posteriorly almost to the equal level to that of the axial element, assuming different features. But, the dorsal terminal has rather the common feature in the posterior portion in the species herein dealt with, though short in the extremity (Figs. 7, 12 and 13).

Dorsal terminal, d. tr. 1 :- This cartilage is located on the dorsal side of the glans clasper, more or less covering the other dorsal terminals, d. tr. 2 and 3. Though marked differences are found in the features of the d. tr. 1 according to the features of the pseudosiphon in the rajids species examined herein, little attention has been paid to the fact up to the present day. Nevertheless, it seems very difficult to show the exact form of the cartilage in the various species of the fish partly owing to the poor calcification and partly to the curious design. By paying the greatest possible care to the anatomy of the cartilage, however, the present writer emphasizes that the characteristics in the cartilage represent remarkable modification in the respective species as seen in Fig. 8.

This fact may probably make us firmly the following conception; 1) the cartilage in the northern members is provided with idiomorphic feature in most cases that may

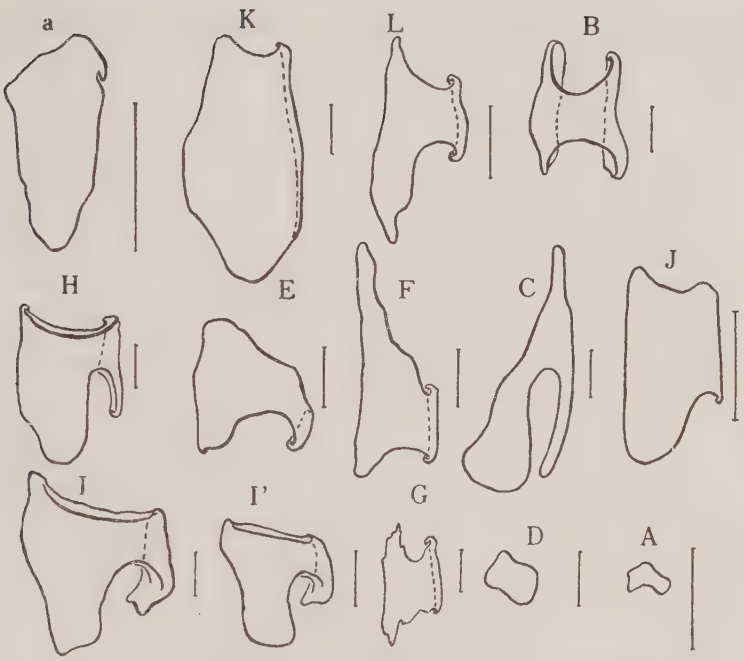

Fig. 8. Dorsal views of the dorsal terminal, d. tr. 1 in thirteen forms in the organ of Type-CNI, coupled with the cartilage of *Rhinobatos schlegeli*, a; especially showing these elements are in species-specific feature, based on which, but conveniently, twelve types, Dt^A to Dt^K were assorted. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*; I', *B. smirnovi ankasube*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*. Scales represent 1 cm.

serve for discrimination between species or even between much more related forms, and 2) it may be possible to suppose that there is some linealogical relationship on the basis of these differentiation revealed in the cartilage.

Taking the above into consideration, we give account of these features in the cartilages, using the abbreviations Dt^A to Dt^K.

It should be noticed herewith the cartilage in the species K is most akin to that of *Rhinobatos schlegeli*, a representative of Rhinobatidae, in which the cartilage is large without any noticeable reduction being seen (a and K in Fig. 8).

Other dorsal terminals, d. tr. 2 and 3:- These cartilages are developed on the dorsal border of the glans clasper as in case of the preceding element, with the pseudosiphon inserted between the d. tr. 1 and the elements in question. Usually, the two cartilages are coexisting element tightly blended with each other, and are closely stuck basally to the dorsal marginal.

Since the cartilages are very thin and their posterior marginal portions are ill-defined due to the poor chondrification even in the masculinized organ, it may be rather difficult to grasp the exact features of the elements in each species. On the basis of the cartilages the following evidences may be summarized; 1) features in the cartilages seem to show species-specific characteristics, and 2) they are roughly in

concord with those linealogical trends found in the d. tr. 1. These evidences could naturally be seen from Fig. 9, if we could guess the courses of the transformation in the cartilages, but in doing so, we should fail to lead to a plausible conception.

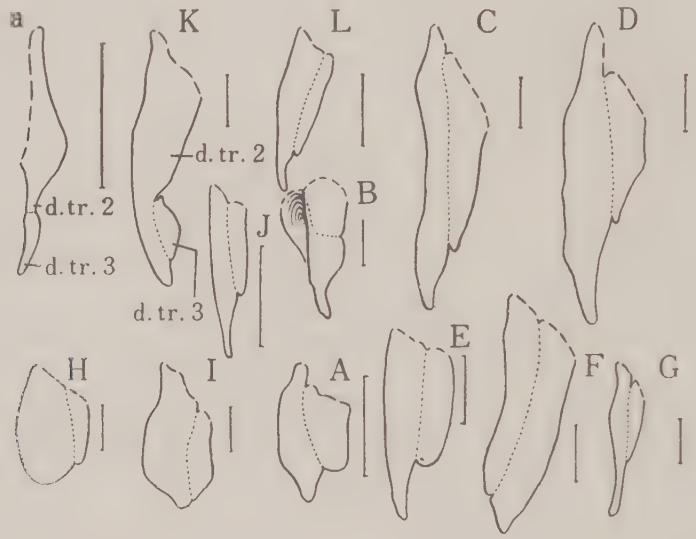

Fig. 9. Dorsal views of the dorsal terminals, d. tr. 2 and 3 in twelve forms of the Japanese rajids, coupled with that of *Rhinobatos schlegeli*, a; broken line indicates the junction of the d. tr. 2 to the d. mg.; dotted line represents the boundary where the two elements are tightly blended. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*. Scales denote 1 cm.

Ventral terminal, v. tr.:- On the ventral border of the glans clasper the ventral terminal is located connected with the posterior of the ventral marginal. The differentiations in the cartilage are very complex as in the dorsal terminals, being also taken as idiomorphic in our species, but the element is stiffened and well-outlined in nature (Fig. 10). For further explanation the author has dared to classify the cartilages into five types (Vt^1 to Vt^5), basing them only on those morphological evidences in the elements.

Type-Vt^1 is found in the species **K**, in which the cartilage is of J-like shape somewhat resembling that of *Rhinobatos schlegeli* (**a** and **K** in Fig. 10). Type-Vt^2 is exemplified by the feature revealed in species **J**, whose element is reduced in its posterior portion (**J** in Fig. 10). Type-Vt^3 is modeled after the characteristics in the three species (**A**, **C** and **D**); the cartilage is developed in hook-like shape posteriorly (**A**, **C** and **D** in Fig. 10). Type-Vt^4 is found in the six species, **B**, **E**, **F**, **H**, **I** (**I'**) and **L**; the element is of spoon-like shape with more or less thickened posterior portion (**B**, **E**, **F**, **H**, **I**, **I'** and **L** in Fig. 10). Type-Vt^5 is found in the species **G**; the cartilage is reduced into a very small slender element (**G** in Fig. 10.).

Accessory terminals, a. tr. 1 and 2;- The accessory terminal is developed with two small cartilages in the three species **A**, **C** and **D**. But in the other species, only

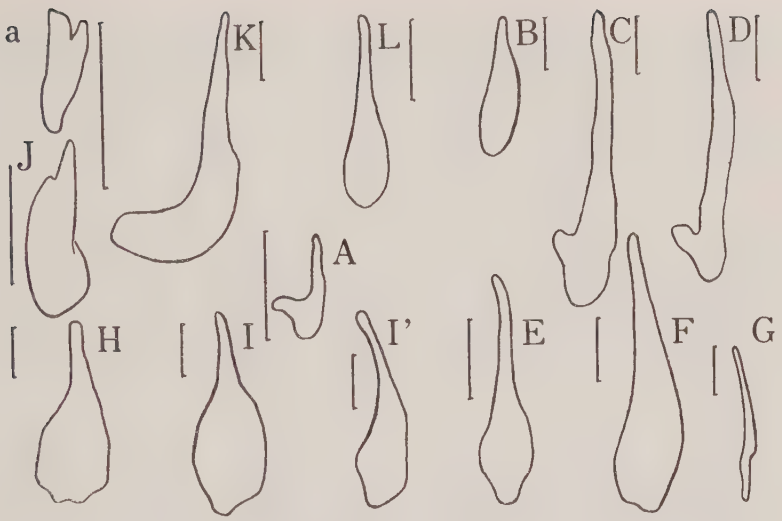

Fig. 10. Dorsal aspects of the ventral terminals, v. tr., of thirteen forms of the Japanese rajids, coupled with that of *Rhinobatos schlegeli*, a; especially showing these elements represent rather idiomorphic feature, based on which, for convenience' sake, five types, Vt^1 to Vt^5, were assorted. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*; I', *B. smirnovi ankasube*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*. Scales denote 1 cm.

the a. tr. 1 is developed more or less regularly. In either group of the species, the cartilages grow at the emergence of the ventral marginal from the axial cartilage, and the a. tr. 2 is, if present, located on the lateral side of the a. tr. 1. The cartilages are developed in intimate relation to the degree of development of either the spur or the knife in the external structure of the organ.

The features of the cartilages have remarkable interspecific differences as outlined in Fig. 11, which may give us a good idea in distinguishing the fact rather than any information on the form of the elements. For brevity's sake, however, the present writer has defined those characteristics in the cartilages, classifying them into six types called At^1 to At^6.

Type-At^1 involves four species (**B**, **F**, **G** and **K**); the a.

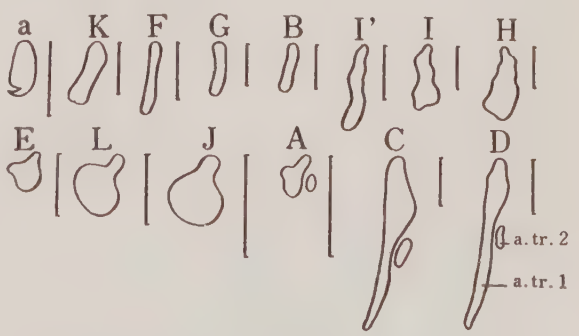

Fig. 11. Dorsal views of the accessory terminals, a. tr. 1 and 2, in thirteen forms of the Japanese rajids, contrasted to that of *Rhinobatos schlegeli*, a; especially notifying these cartilges represent complex outline, on the basis of which six types, At^1 to At^6, were assorted. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*; I', *B. smirnovi ankasube*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*. Scales denote 1 cm except species a being 0.5 cm.

tr. 1 is developed in a small rod with a smooth surface (**B**, **F**, **G** and **K** in Fig. 11). Type-At^2 is found in the two species (**H**, **I** and its subspecies **I′**); the element is somewhat thickened with complex configuration (**H**, **I** and **I′** in Fig. 11). Type-At^3 is found in only species **E**, in which the cartilage is very small and broad in shape (**E** in Fig. 11). Type-At^4 involves two species (**J** and **L**); the element is like a round fan in shape with a keen edge in posterior margin (**J** and **L** in Fig. 11). Type-At^5 has a curious form as found in the species **A** (**A** in Fig. 11), where both a. tr. 1 and 2 are present, but the former is furnished with a keen edge as found in the preceding species (**J** and **L**). Type-At^6 is exemplified by the two species (**C** and **D**); the cartilage is developed with two elements, of which the a. tr. 1 is very long and stout, while the other is small, looking like a rod (**C** and **D** in Fig. 11).

It must be noticed here that the cartilage in the organs of both *Rhinobatos schlegeli* and *Platyrhina sinensis* is highly different from one of the Japanese rajids in having a sharp spine called the claw in the external structure (Figs. 10, 20; a, a″, b).

§§. Subordinate division of the northern forms on the basis of the internal features of their glans claspers (Type-CNI):- Judging from the general features of the cartilages which form the characteristics of the clasper in each species of the type CNI, we can emphasize that the organ seems to have unique feature in each species which can not be seen in any other internal features. But, in order to make these differential characteristics in the organ quite distinguishable, the writer has classified this type into seven subtypes abbreviated as Types-CNI^1 to -CNI^7 in contrast to those done in the external character.

Type-CNI^1 has in it only one species **K** (**K** in Fig. 12); the characteristics in the organ of this type are found in d. tr. 1 of Type-Dt^1 and v. tr. of Type-Vt^1, which are somewhat alike to those in *Rhinobatos schlegeli*.

Type-CNI^2 is the characteristics in the organs of the two species **J** and **L** (**J** and **L** in Fig. 12); the distinguishable features in these examples are d. tr. 1 and a. tr. The d. tr. 1 is somewhat reduced in the species **J**, but in the **L** it is more degenerate. This is also observed in the modification of the v. tr. in the organs of the two species. Further, the feature of the a. tr. is conspicuous in this type (as in Type-At^4).

Type-CNI^3 has only one species **A** (**A** in Fig. 12); the characteristics in the structural elements are found in remarkably reduced d. tr. 1 and also found in hook-like v. tr., and two accessory terminals connected with a slender posterior projection of the ventral marginal.

Type-CNI^4, in which the species **B** is involved (**B** in Fig. 12), is distinguished from the other types in having specialized d. tr. 1, 2 and 3, which seem modified from those in the type CNI^2, and in having v. tr. of Type-Vt^4.

Type-CNI^5 is found in the organs of the two species **C** and **D** (**C** and **D** in Fig. 12); these representatives closely resemble each other in both external and internal features of the organ, but they are discriminative internally in d. tr. 1. More exactly, the d. tr. 1 in the species **C** is in a curious design (as in Type-Dt^C) that may have been modified and reduced from that of a species like **K**. But in the species **D** which has the element of a small quadrangular shape, the cartilage is much more reduced than in the former species (as in Type-Dt^D). The two species may distinctively differ from the others in having specialized dorsal and ventral marginals, and in having axial cartilage of Type-Ax^2, ventral terminal of Type-Vt^3 and accessory terminals composed of two elements belonging Type-At^6.

Type-CNI^6 has in it three species, viz., **E**, **F** and **G** as illustrated in Fig. 13.

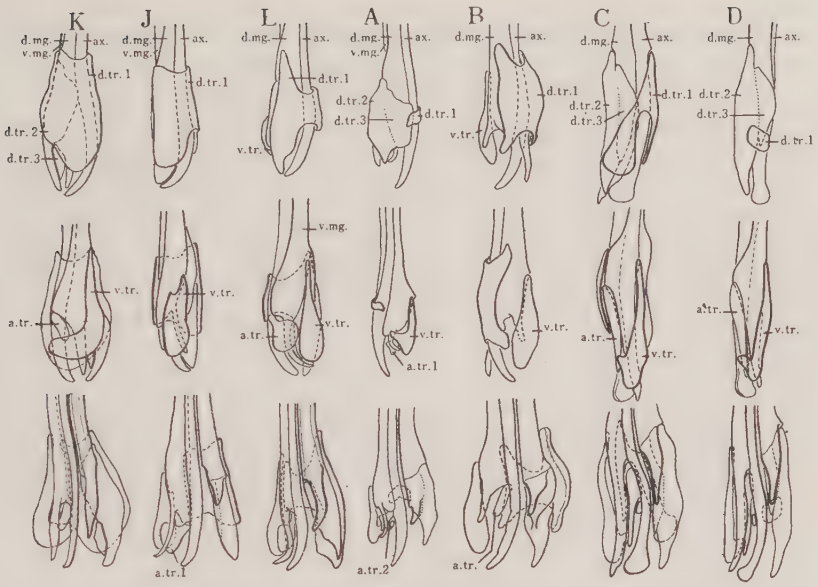

Fig. 12. Showing the arrangement of the cartilages in the glans clasper in seven forms of the organ (Type-CNI), which is subdivided into five subtypes, CNI[1] to CNI[5]. Upper row, dorsal aspects; middle and lower ones, ventral and opened views, respectively. a. tr., accessory terminal; ax., axial cartilage; d. mg., dorsal marginal; d. tr. 1—3, dorsal terminals; v. mg., ventral marginal; v. tr., ventral terminal. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.* All these Figs. were drawn in the same size for the sake of comparison, and so forth.

These examples are distinguished from any other type in having such similar characteristics in the axial cartilage represented as Type-Ax[1] and in having dorsal and ventral marginals, but the three species are distinguishable each other in some elements, dorsal and venral terminals. Judging from these characteristics in the elements the present writer can safely say that the species **E** is more related to **F** than to **G**.

Type-CNI[7] involves fishes **H**, **I** and its subspecies **I′** (**H**, **I** and **I′** in Fig. 13), which are very closely related to both features and arrangement of the cartilaginous elements in the organ, though we can not say much about their congeneric relations between species **H** and **I** (**I′**) recognized in external features of the organs. The present type of the organ may be distinct from the others in having marked peculiarity in features of the axial cartilage of Type-Ax[3], the dorsal terminal and the accessory terminal. It may be worth mentioning here that the differences in the features of such elements are more distinct between the species **H** and the two subspecies **I** and **I′** rather than that recognized between the latters, in which the features found in the ventral terminal and the accessory terminal are distinguishable each other. The present writer believes that this fact shows a subspecific variation actually originated in the male organ.

♀♀. **Type-CSI of the myxopterygial cartilages:-** The clasper of this type is found in the organ of the southern form, and is composed of eight elemental cartilages in most species but occasionally more numerous, which are fundamentally of the same composition as those found in the preceding type, although both features and arrange-

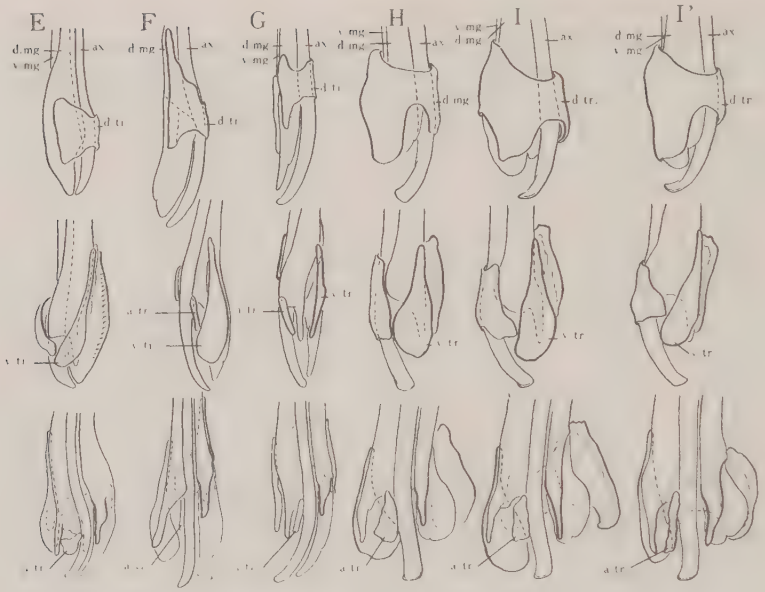

Fig. 13. Showing the arrangement of the cartilages in the glans claspers in six forms of the organ (Type-CNI), which was classified into two subtypes, CNI^{6} and CNI^{7}. Upper row, dorsal views; middle and lower ones, ventral and opened views, respectively. a. tr., accessory terminal; ax., axial cartilage; d. mg., dorsal marginal; d. tr. 1—3, dorsal terminals; v. tr., ventral terminal. E, *Breviraja diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* I', *B. smirnovi ankasube.*

ment of the elements are markedly different between these two types (l. c.). Therefore, the present writer has made first detailed descriptions of the structural elements and followed typification of the characteristics as has been done in the previous section.

Axial cartilage, ax.:- The axial cartilage of this type is the same in its general feature as that of the preceding one, especially in its main portion and the relative position in the organ, but the distal end of the cartilage usually forms a shallow hook in this type except for the species **P**, in which the element ends in a slender and pointed tip (**P** in Fig. 17). Another difference in the feature of the cartilage between the two types is a projection which more or less develops in the midway portion of the cartilage of this type so as to connect itself with the dorsal terminals, d. tr. 2 and 3. The projection is obscure in the cartilages of the three species **M**, **Q** (**Q'**) and **T** (ax. in Figs. 17—19), but it is distinctively developed in those of other species of this type, especially so conspicuous in the species **N**, **P**, **U**, **V** and **W** (Figs. 17 and 19).

Dorsal marginal, d. mg.:- In both feature and location in relation to other cartilages in the clasper, the dorsal marginal of this type is specialized only in the posterior portion as compared with that of the preceding type. The element is broadened posteriorly, ending in an asymmetrical bifurcation (d. mg. in Figs. 17 and 18).

Ventral marginal, v. mg.:- On the ventral side of the glans clasper the ventral marginal is developed, covering the axial cartilage and broadened posteriorly. This cartilage, however, has almost the same feature in this type in question (v. mg. in

Figs. 17 and 18).

Dorsal terminals, d. tr. 1, 2 and 3 :- As in the preceding type the dorsal terminals are composed of three elements. But, there is a marked difference in the features of these three cartilages between the two types. Of the three, the dorsal terminal, d. tr. 1, is remarkable in its size, being scrolled and incurved so as to cover the outermost dorsal border of the glans. Such being the case, the cartilage can be divided into two parts, the dorsal and the ventral half. The dorsal half is usually larger than the ventral one, but the reverse is the case in some instances. More exactly, the dorsal half is well developed in a triangular shape in the five species **M, N, P, S** and **T,** but is tapered in **Q** (**Q′**) and **R,** or is quadrangular (**V** and **W**), and the cartilage is polygonal in its outline in the two examples **O** and **U** (d. tr. 1 in Fig. 14).

So far as the outline of the cartilage is concerned, the element in this group of the fish can be classified into four types, which the writer called Type-Dt^{a} to -Dt^{d} as explained in Fig. 14. Type-Dt^{a} involves the five species **M, N, P, S** and **T;** Type-Dt^{b} is found in the two forms **Q** (**Q′**) and **R;** Type-Dt^{c} involves two species **V** and **W,** and Type-Dt^{d} may be represented by the two forms **O** and **U.**

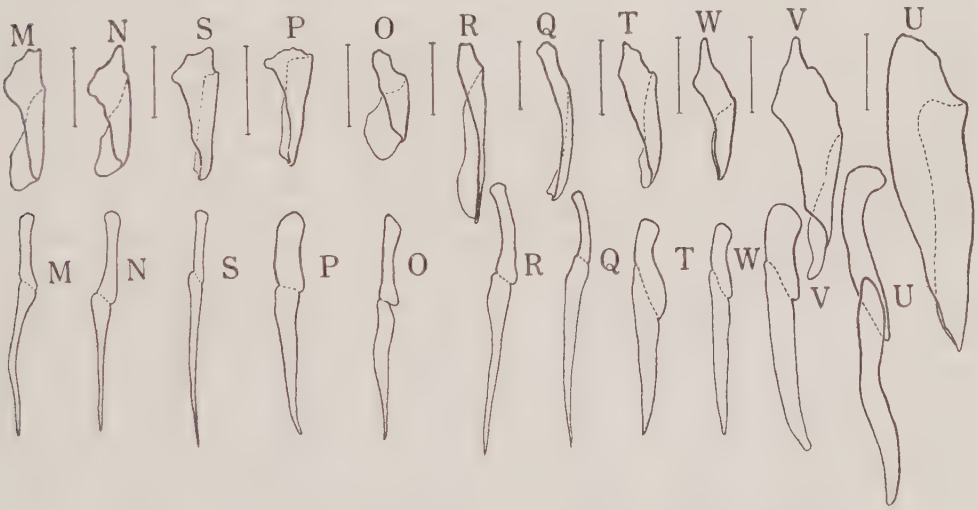

Fig. 14. Dorsal views of the dorsal terminals, d. tr. 1, 2 and 3, of eleven forms of the Japanese rajids, representing Type-CSI of the organ. Upper, d. tr. 1, on the basis of which four types (Dt^{a} to Dt^{d}) were assorted; lower, d. tr. 2 and 3, in which semicartilaginous portion is dotted. **M,** *Raja kenojei;* **N,** *R. acutispina;* **O,** *R. hollandi;* **P,** *R. macrophthalma;* **Q,** *R. porosa meerdervoorti;* **R,** *R. fusca;* **S,** *R. schmidti,* **T,** *R. tengu;* **U,** *R. pulchra;* **V,** *R. macrocauda;* **W,** *R. gigas.* Scales attached to Figs. from **M** to **S** represent 1 cm, but 2 cm in the rest.

Other dorsal terminals, d. tr. 2 and 3 :- These two cartilages are developed in bar-like elements which ensue rearward from the rear end of the dorsal marginal. It should be noticed herewith that the articulation of the d. tr. 2 to distal end of the dorsal marginal is distinct in this type of the organ. The d. tr. 2 is usually shorter than the d. tr. 3, which becomes gradually slenderer posteriorly, forming semicartilaginous tissue to which the tip of the axial cartilage is attached, making a marginal frame of the dorsal lobe of the glans clasper.

Both shape and size of the cartilages seem to have similar tendencies in the

transformation to those noticed in the d. tr. 1, as has been described above. Therefore, the writer has only delineated the cartilages together with the d. tr. 1 (Fig. 14).

It may be of special interest in the cartilages found in the species **U** that a small bar-like element is developed to make a connection between the posterior end of the d. tr. 2 and the projection of the axial cartilage. This unique cartilage is newly termed here 'terminal bridge', which may be an offshoot derived from the accessory terminal described below (t. br. in Figs. 16 and 18).

In summarizing the differentiation revealed in the three dorsal terminals, the writer has presumably found that the evidence worthy of giving specific features leads him to probable relationship in the type.

Ventral terminal, v. tr. :- The ventral terminal of this type of the organ is a very large cartilage with a very complex feature which is markedly differentiated from that in the preceding type, CNI. The cartilage grow in the ventral lobe of the glans to form a frame of the lobe. Anteriorly, the element has a deep notch, in most cases, to which the basal part of the left arm of the accessory terminal 1 is attached. The main portion of the element can be divided into two parts in the ventral aspect; a portion which directs outwards is furnished with a knife-blade-like edge which is called 'shield' in the external observation; the other which is on the inner ventral border of the cartilage more or less developed from a thin cartilage forming an irregular margin on the ventral side of the element. These two parts are bounded by a longitudinal depression.

In the distal part of the cartilage a semicartilaginous projection is developed, tapering off more or less, connecting the posterior tip of the axial cartilage with it. The projection is regarded as a form of the dike in the external.

In order to clarify these complex features revealed in the ventral terminal outlined

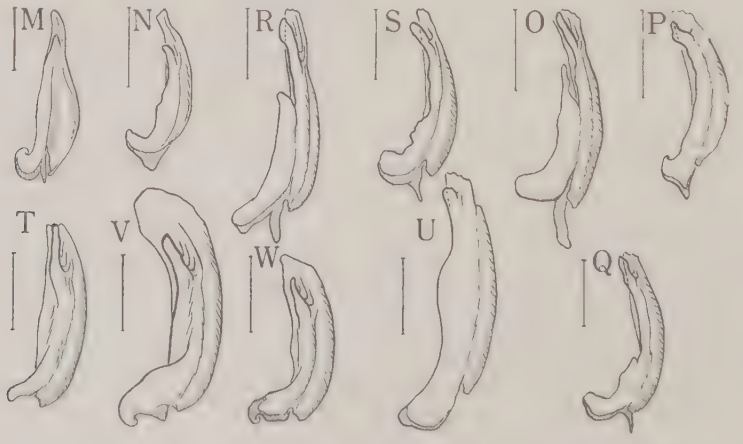

Fig. 15. Ventral aspects of the ventral terminal, v. tr., in the twelve forms of the Japanese rajids (Type-CSI of the organ), especially showing interspecific variations on anterior portion bifurcated, knife-blade-like margin, inner thin cartilage and posterior projection tapering off, based on these characteristics the cartilage were classified into six types, Vt^a to Vt^f. M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi,* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti;* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.* Scales denote 1 cm, except those four examples (T—W) with bars of 2 cm.

above, the present writer has assorted the members in this type basing them on, i) feature of the anterior portion with notches, ii) degree of development of the knife-blade-like edge, iii) form of the inner thin cartilage with an irregular outline, and iv) degree of development of the posterior projection tapering off.

Comparing these characteristics in the cartilage that seem to have some validity in speculating the degree of differentiation of the cartilage, the writer has classified species into six groups, as follows, abbreviating them as Type-Vt^{a} to -Vt^{f}.

Type-Vt^{a} involves two species, **M** and **N**, whose characteristics in the cartilage are moderately developed in any and every category itemized above (**M** and **N** in Fig. 15). Type-Vt^{b} is found in the feature of the species **P**, **Q** and **S**, where the anterior portion, inner thin cartilage and posterior projection are somewhat conspicuous (**P**, **Q** and **S** in Fig. 15). Type-Vt^{c} is exemplified by the two species **O** and **R**, which are specialized in the features, such as anterior portion, inner thin cartilage and posterior projection (**O** and **R** in Fig. 15). Type-Vt^{d} involves only one species **T**, in which any of the features in the cartilage can not be noticed as specialization except for the feature revealed with the anterior portion (**T** in Fig. 15). Type-Vt^{e} involves the two species **V** and **W**, which can be distinguished from the preceding species by having much specialized features in the anterior portion and knife-blade-like cartilage (**V** and **W** in Fig. 15). Type-Vt^{f} is found in the cartilage of the species **U**, which can be clearly distinguished from any other form mentioned above in having much more specialized features in regard to those four categories itemized above than those in the preceding species (**U** in Fig. 15).

Accessory terminals, a. tr. 1 and 2 :- The accessory terminals are developed with specialized two elements. Of the two, the a. tr. 1 starts off anteriorly from a portion where the ventral marginal ends in a round margin. The a. tr. 1 assumes Y-like shape in most species in question, bifurcated anteriorly with two symmetric or asymmetric arms. From Fig. 16 we can recognize the transformation in the anterior arm which changes from symmetric form to asymmetric one. The posterior arm, however, is developed in different forms, as simply elongated, broodly pointed or sharply edged.

The accessory terminal 2 is also developed in different design with specialized features in most cases. The cartilage originates together with the right arm of the a. tr. 1, attached to posterior edge of the ventral marginal. Posteriorly, the a. tr. 2 is developed with specialized portions, which are termed here for the sake of convenience to be described as the attachment and the spinal projection (at. and pr. in Fig. 16).

The attachment grows more or less regularly at the midway point of the a. tr. 2, firmly attached to the lateral side of the axial cartilage, except for the species **T**, in which the attachment is absent. The spinal projection varies with the posterior elongation, which projects posteriorly as a slender and snarled cartilage sharply pointed or hooked at the distal tip. The projection was regarded as the spike in the external observation.

The a. tr. 1 in the organ of the species **U** is so conspicuous as to be noticed with special mention. Namely, the cartilage in this species is composed of three separate elements; the one with spoon-like shape located on the ventral border of the axial cartilage is newly called here 'detachment' as a substitute for the attachment, (dt. in Fig. 16 **U**); a boot-like element which ensuing posteriorly from the detachment may be a modification from the spinal projection of the accessory terminal 2 mentioned above (a. tr. 2 in Fig. 16 **U**); the terminal bridge which has been described in the preceding paragraph may be a fraction derived from the a. tr. 2 (t. br. in Fig. 16

U).

These two accessory terminals which assume markedly diversified features in this type of the organ as outlined above may be co-acting element that render the fish some fundamental service in copulation. In accordance with the characteristics thus mentioned the present writer has classified a group of these two cartilages into six types, viz., At^a to At^f.

Type-At^a is found in the species **T**, in which the a. tr. 1 is furnished anteriorly with asymmetrical arms and a simply elongated posterior projection, and the a. tr. 2, with a slender projection, but without the attachment (**T** in Fig. 16). Type-At^b involves three examples (**M**, **V** and **W** in Fig. 16); the a. tr. 1 is developed in the same manner as in the preceding species, but the a. tr. 2 is furnished with the attachment more or less developed, and the spinal projection is hooked posteriorly in some extent. Judging from these facts revealed in the two types mentioned above, the species **T** may be regarded as the simplest feature of the cartilages, from which those three species represented as the Type-At^b may have been diversified with different features. Type-At^c can be found in the organ of the following four species (**N**, **Q**, **R** and **S** in Fig. 16); the anterior arm of the accessory terminal 1 is rather

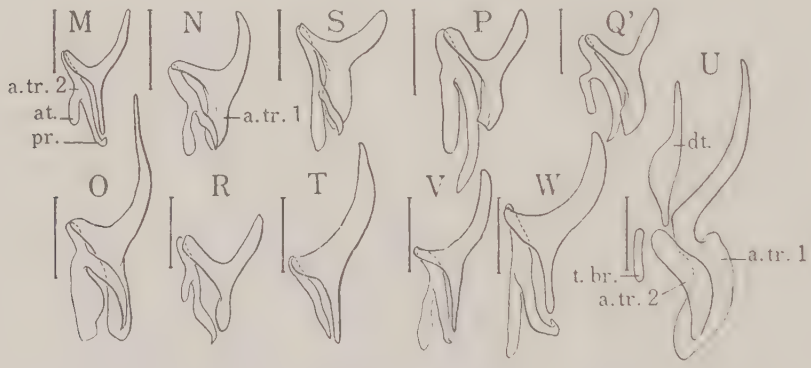

Fig. 16. Ventral views of the accessory terminals, a. tr. 1 and 2 in eleven forms of the Japanese rajids (Type-CSI of the organ), especially showing Y-shaped outline in the a. tr. 1, the attachment (at.) branched out from the a. tr. 2 with or without either hooked or snarled posterior projecton (pr.) and four fractions of the a. tr. 1 and 2 developed in species **U** (a. tr. 1, a.tr. 2, dt. and t. br.). On the basis of these features the cartilages are assorted into six types as explained in the text. **M**, *R. kenojei*; **N**, *R. acutispina*; **O**, *R. hollandi*; **P**, *R. macrophthalma*; **Q'**, *R. porosa tobae*; **R**, *R. fusca*; **S**, *R. schmidti*; **T**, *R. tengu*; **U**, *R. pulchra*; **V**, *R. macrocauda*; **W**, *R. gigas*. Scales represent 1 cm in species from **M** to **R**, but 2 cm from **T** to **W**.

in symmetrical form, and the posterior one is broadened with a pointed distal tip; the a. tr. 2 is in moderate degree of development, furnished the attachment and the spinal projection more or less snarled. We must specially mention here the finding of critical difference between the two forms **Q** and **Q'** in structural evidence of the two elements, viz., the spinal projection of the a. tr. 2 in **Q** is elongated posteriorly reaching as far as the posterior arm of the a. tr. 1, but the projection sticks out posteriorly beyond the distal tip of the posterior arm in **Q'** (Figs. 16 and 18). In the writer's sense this difference in the features of the two cartilages between these two forms may surve as good basis for separating them into two subspecies which

are closely related to the external features as will be explained elsewhere (cf. p. 173). Type-At^{d} involves only one species O as illustrated in Fig. 16; the anterior arm of the a. tr. 1 is asymmetrical due to much elongation in the left arm, and the posterior arm is developed with a long, stout projection which furnishes the distal margin with a keen edge; the attachment of the a. tr. 2 is swollen up, and the spinal projection assumes the form of a very sharp spine like a spindle. Type-At^{e} is exemplified by only one species P; the a. tr. 1 has symmetrical arms anteriorly, and the posterior one is thickened with a knife-blade-like edge in its rear end; the a. tr. 2 is remarkably developed with a long attachment and a spinal projection (P in Fig. 16). Type-At^{f} involves but one species U, whose a. tr. 1 is highly specialized by having a long anterior arm and a large axe-like posterior one which furnishes the outer margin with a knife-blade-like edge; the a. tr. 2 is also curious in having the

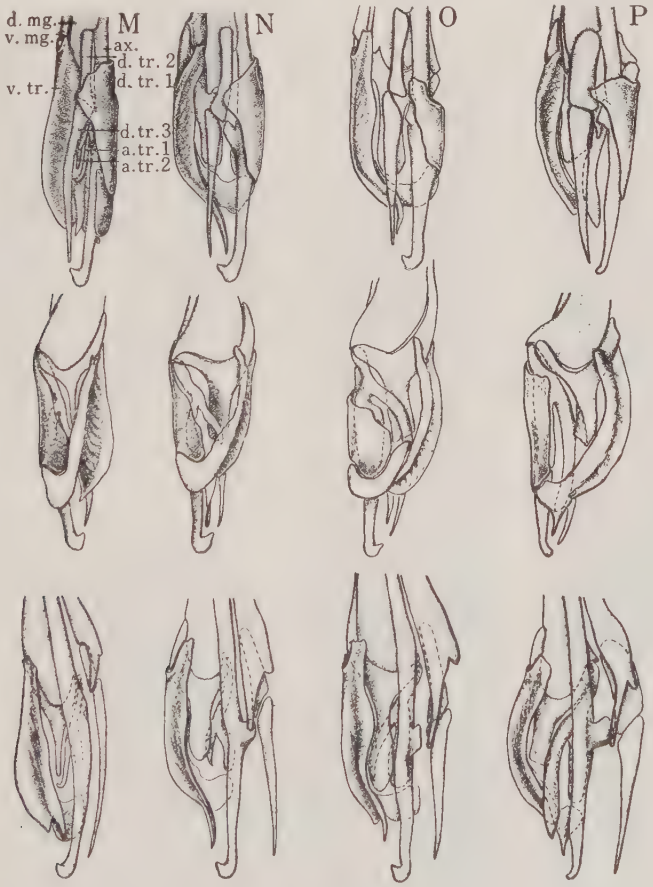

Fig. 17. Showing the structural elements in the glans claspers of four forms of the organ (Type-CSI). Upper row, dorsal views; middle and lower ones, ventral and opened views, respectively. a. tr. 1 and 2, accessoy terminal 1 and 2, respectively; ax., axial cartilage; d. mg., dorsal marginal; d. tr. 1, 2 and 3, dorsal terminal 1, 2 and 3, respectively; v. mg., ventral marginal; v. tr., ventral terminal. M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*. All these Figs. were given in similar size.

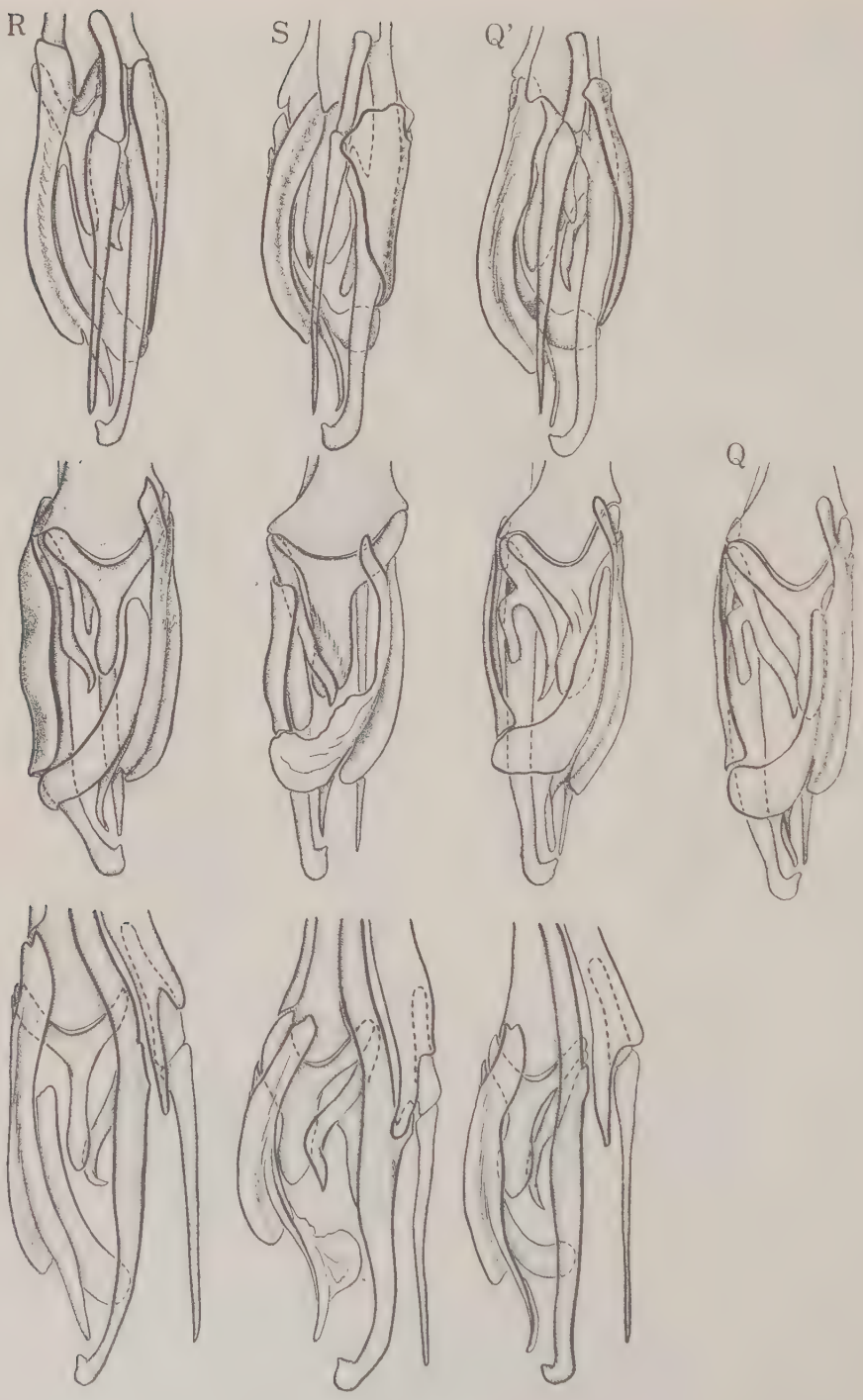

Fig. 18. Showing the arrangement of the elements in the glans claspers of five forms of the organ (Type-CSI). Upper row, dorsal views, middle and lower ones, ventral and opened views, respectively. Q, *Raja porosa meerdervoorti;* Q', *R. porosa tobae;* R, *R. fusca;* S, *R. schmidti;* other abbriviations are the same as in Fig. 17, and all these Figs. were drown in an equal size.

three fractions derived from the cartilage as mentioned above (U in Fig. 16).

§§. Subordinate division of the southern forms on the basis of the internal features of their glans claspers (Type-CSI):- Thus having scrutinized comparatively the internal features found in the claspers of the Type-CSI, the writer has come to the conclusion that any sort of classification of the organ might be difficult to show in complete system because of the greatest diversifications revealed in the organ of this type. But marked differentiations can naturally be recognized especially in the following cartilages, i) both dorsal and ventral terminals, and ii) accessory terminals. According to the differential features of these elements the writer has assorted them into several types.

The following six subtypes may be discriminated in reference to these internal features of the organ concerning the type of glans clasper.

Type-CSI^1 involves only species **M**, in which the most diagnostic feature may be noticed to the accessory terminals of Type-At^b, but the dorsal terminal 1 as well as the ventral terminal is also somewhat attractive (**M** in Fig. 17).

Type-CSI^2 is modeled after the characteristics of the organs in the four species **N**, **Q** (**Q′**), **R** and **S**. But these examples seem to differ from one another in the characteristics of the dorsal and accessory terminals. In the species **Q** (**Q′**) and **R**, the dorsal terminal 1 tapers off in Type-Dt^b, though species **N** and **S** have Type-Dt^a, and the accessory terminals of the group of species have been typified as At^c, and the features of the ventral terminal are different in these four species belonging to Type-Vt^{a-c} (**N**, **Q** (**Q′**), **R** and **S** in Figs. 17 and 18).

Type-CSI^3 is found in the species **O** and **P**. These two examples are somewhat analogous in those characteristics, such as the dorsal, ventral and accessory terminals, which clearly make us discriminate this type from any other relatives (**O** and **P** in Fig. 17).

Type-CSI^4 is exemplified by only species **T**, in which the ventral terminal has Type-Vt^d and the accessory terminal shows Type-At^a. And this fact is characteristic of this type (**T** in Fig. 19).

Type-CSI^5 is found in the species **U**, whose organ seems much more specialized than in the former in having the ventral terminal of Type-Vt^f and the accessory terminal of Type-At^f, and the latter is the most

Fig. 19. Showing the arrangement of the cartilage elements in the glans claspers of four forms of the organ (Type-CSI). Upper row, dorsal views; middle and lower ones, ventral and opened views, respectively. T, *Raja tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

distinguishable characteristics in the elements (U in Fig. 19).

Type-CSI[6] involves the two species V and W, about which the writer has called the reader's attention to the fact that they are having ventral terminal of Type-Vt[e] and accessory terminal of Type-At[b] (V and W in Fig. 19).

According to the comparative investigation of the internal feature of the glans claspers of Japanese rajids as aforementioned, the characteristics in the organ of the respective types may be shown in the following Table.

Table 3. Internal characteristics of the glans claspers of the Japanese rajids classified into two major types (CNI and CSI) followed by their subtypes. The abbreviations except followings refer the reader to the text; ax., axial cartilage; a. tr., 1, 2, accessory terminal 1, 2; d. mg., dorsal marginal; d. tr. 1—3, dorsal terminal 1—3; v. mg., ventral marginal; v. tr., ventral terminal; + and — represent the presence and absence of the cartilage, respectively.

Type	CNI							CSI					
Subtype / Items	1	2	3	4	5	6	7	1	2	3	4	5	6
ax.	Ax^1	Ax^1	Ax^1	Ax^1	Ax^2	Ax^1	Ax^3	hooked	hooked	hooked or pointed	hooked	hooked	hooked
d. mg.	+	+	+	+	+	+	+	+	+	+	+	+	+
v. mg.	long	long	short	short	long	long	short	+	+	+	+	+	+
d. tr. 1	Dt^K	$Dt^{J;L}$	Dt^A	Dt^B	$Dt^{C;D}$	Dt^{E-G}	$Dt^{H;I}$	Dt^a	$Dt^{a;b}$	$Dt^{a;d}$	Dt^a	Dt^d	Dt^c
d. tr. 2, 3	+	+	+	+	+	+	+	+	+	+	+	+	+
v. tr.	Vt^1	$Vt^{2;4}$	Vt^3	Vt^4	Vt^3	$Vt^{4;5}$	Vt^4	Vt^a	Vt^{a-c}	$Vt^{b;c}$	Vt^d	Vt^f	Vt^e
a. tr. 1—3	At^1	At^4	At^5	At^1	At^6	$At^{1;3}$	At^2	At^b	$At^{d;e}$	$At^{d;e}$	At^a	At^f	At^b
Genus	*Rhinoraja*		*Breviraja*					*Raja*					
Species	K	J;L	A	B	C;D	E;F;G	H;I	M	N;Q;R;S	O;P	T	U	V;W

3. Discussion

(1). Systematic significance of the characteristics related to the clasper:

In elasmobranchs, LEIGH-SHARPE (1926) presumed that "..... genera, and in some cases even species (*Chimaera*, *Cestracion*, many *Raia*), can be distinguished by those characters ....., and it is abundantly clear that they will in future have to be used for purpose of identification."

By the comparative investigation of the characteristics in both external and internal features of the clasper in each species of the Japanese rajids, the following evidence has been confirmed to be present, which will serve for making out the sound basis formed on: i) features in both external and internal structures of the clasper are species specific without exception; ii) intra-specific variations are seemingly recognizable in minor scale; iii) specific characteristics in the organ worthy of merit for an analytical classification of the fish dealt with in this study; and iv) phyletic relations between genera and between species, or even subspecies in some cases, of the family are conclusively presumed by those transformations of the features in the organs.

(2). Analytical key to genera, species and subspecies of the Japanese rajids:

The following key has been based on both external and internal characteristics of the clasper, and it has been found to exhibit the natural affinities of the species in each group according to their genealogical trends in the characteristics.

1a. Clasper club-type, usually with a blunt distal tip; glans clasper composed externally

of ten components, namely, pseudosiphon, slit, ridge, pseudorhipidion, spur, scale, pent, funnel, knife, and claw, some of which are absent in some species, and internally composed of eight or nine cartilage elements, viz., axial cartilage (ax.), dorsal and ventral marginals (d. mg. and v. mg.), three dorsal terminals (d. tr. 1, 2 and 3), and one or two accessory terminals (a. tr. 1, 2); (Figs. 2～4 and 7～12).

2a. Pseudosiphon distinct, broadly opening on the dorsal border apart from distal tip of glans clasper (Type-Ps^{1}); dorsal terminal 1 large, without remarkable reduction; ventral marginal elongate posteriorly, as long as axial cartilage, of which the distal tip pointed or blunt (Type-Ax^{1}) ..... *Rhinoraja*

3a. Type 1: Both pseudorhipidion and funnel well-developed; knife and claw absent; dorsal terminal 1 complete, covering the whole dorsal side of glans clasper (Dt^{K} in Fig. 8); dorsal terminal 2 large, connecting with it small dorsal terminal 3; ventral terminal J-shaped (Type-Vt^{1}); accessory terminal small, rod-like in shape (Type-At^{1}) ..... *Rh. kujiensis* (**K** in Figs. 2, 4 and 12)

3b. Type 2: Both pseudorhipidion and funnel absent or ill-defined; knife and claw present; inner side of dorsal terminal 1 more or less reduced; ventral marginal elongated posteriorly into a slender, curved projection; dorsal terminal 2 and 3 subequal in size, located side by side; ventral terminal not J-shaped but heteromorphic; accessory terminal round, fan-like shaped (Type-At^{4}).

4a. Slit distinct; dorsal terminal 1 less reduced (Dt^{J} in Fig. 8); ventral terminal somewhat reduced in Type-Vt^{4} ..... *Rh. odai* (**J** in Figs. 4 and 12)

4b. Slit absent; dorsal terminal 1 more reduced (Dt^{L} in Fig. 8); ventral terminal spoon-like is shape (Type-Vt^{2}) ..... *Rh. longicauda* (**L** in Figs. 4 and 12)

2b. Pseudosiphon absent, or reduced, if present, in size, shifted to distal tip of shortened glans, except for species **F**, whose pseudosiphon is rather large, falling far apart from distal tip of glans, or pseudosiphon located on the marginal portion of anterior portion or inside border of dorsal lobe; dorsal terminal 1 reduced in some degree; ventral marginal not so elongate posteriorly as axial cartilage, the distal tip is either pointed or truncated, some times spatulated ..... *Breviraja*

5a. Pseudosiphon absent, disappearing from both dorsal and inside borders of glans, so that dorsal terminal 1 reduced to a very small size; two accessory terminals present.

6a. Type 3: Knife and pent present, but funnel and spur absent (Type-Cne^{3}); distal tip of axial cartilage pointed (Type-Ax^{1}); dorsal terminal 1 reduced to a small piece (Dt^{A} in Fig. 8); ventral terminal hooked posteriorly (Type-Vt^{3}); accessory terminals modified to Type-At^{5}. ..... *B. tobitukai* (**A** in Figs. 4 and 12)

6b. Type 5: Knife and pent absent, but funnel and spur present (Type-Cne^{5}); distal tip of axial cartilage spatulated (Type-Ax^{2}); dorsal terminal 1 greatly reduced; accessory terminal 1 very stout, elongated posteriorly (Type-At^{6}).

7a. Both funnel and spur well-developed; dorsal terminal 1 singular in shape (Dt^{C} in Fig. 8)..... *B. trachouros* (**C** in Figs. 4 and 12)

7b. Both funnel and spur less developed; dorsal terminal 1 reduced into a very small quadrangular piece (Dt^{D} in Fig. 8) ..... *B. abasiriensis* (**D** in Figs. 4 and 12)

5b. Pseudosiphon present, reduced in size to some extent, located on the dorsal border or on the marginal, or on the inside border of the glans clasper, so that dorsal terminal 1 more or less reduced in concordance with the degree of development of pseudosiphon; only accessory terminal 1 present.

8a. Pseudosiphon developed on the dorsal border or anterior marginal portion of glans clasper; posterior end of axial cartilage blunt (Type-Ax[1]); accessory terminal rod-like in shape (Type-At[1]) except for the species **E.**

9a. Type 6: Pseudosiphon located on the dorsal border of glans clasper; ridge absent; funnel more or less developed; dorsal terminal 2 and 3 flat, reaching the extremity of axial cartilage.

10a. Glans clasper shortened; pseudosiphon reduced to small size; funnel inconspicuous; slit and spur absent; ventral terminal rather large, broadened posteriorly.

11a. Pseudorhipidion distinct; dorsal terminal 1 is of Type-Dt[E]; ventral terminal spoon-like (Type-Vt[4]); accessory terminal polygonal in shape (Type-At[3]) ..... *B. diplotaenia* (**E** in Figs. 4 and 13)

11b. Pseudorhipidion moderately developed; dorsal terminal 1 reduced to very thin cartilage with Type-Dt[F]; ventral terminal spoon-like in shape with thickened posterior portion (Type-Vt[4]); accessory terminal rod-like in shape (Type-At[1]) ..... *B. matsubarai* (**F** in Figs. 4 and 13)

10b. Glans clasper elongate; pseudosiphon rather large; funnel distinct; both slit and spur present; dorsal terminal 1 less reduced on outer side (Dt[G] in Fig. 8); ventral terminal greatly reduced to a small, slender bar-like element (Type-Vt[5]); accessory terminal elongated, rod-like in shape (Type-At[1]) ..... *B. aleutica* (**G** in Figs. 4 and 13)

9b. Type 4: Pseudosiphon degenerate to a deep groove, shifted to anterior marginal portion of dorsal lobe of glans clasper (Type-Ps[2]); ridge markedly developed; spur slightly growing on ventral lobe; dorsal terminal 1 deeply notched in two sides (Dt[B] in Fig. 8); dorsal terminal 2 and 3 developed in curious design (**B** in Fig. 9); ventral terminal leef-like in shape (Type-Vt[4]) ..... *B. isotrachys* (**B** in Figs 4 and 12)

8b. Type 7: Pseudosiphon developed on inner border of dorsal lobe of glans clasper (Type-Ps[3]); ridge present; distal tip of axial cartilage truncated (Type-Ax[3]); dorsal terminal 1 thickened, forming a deep notch on posterior margin; dorsal terminal 2 large, forming a frame of the ridge; ventral terminal broadened posteriorly (Type-Vt[4]); accessory terminal with complex configuration (Type-At[2]).

12a. Ridge distinctively developed, without scale on dorsal surface; funnel large; both slit and spur obscure; dorsal terminal 1 well-notched posteriorly (Dt[H] in Fig. 8); accessory terminal rather thick (**H** in Fig. 11) ..... *B. parmifera* (**H** in Figs. 4 and 13)

12b. Ridge moderately developed, furnished sparsely with minute scales; funnel absent; both slit and spur moderately developed; dorsal terminal 1 less notched posteriorly; accessory terminal slender.

13a. Ridge less developed, so that dorsal terminal 1 low (Dt[I] in Fig. 8); distal half of both ventral and accessory terminals broadened (**I** in Figs. 10 and 11) ..... *B. smirnovi smirnovi* (**I** in Figs. 4 and 13)

13b. Ridge more distinct, so that dorsal terminal 2 relatively high (Dt[I'] in Fig. 8); distal half of both ventral and accessory terminals rather slender (**I'** in Figs. 10 and 11) ..... *B. smirnovi ankasube* (**I'** in Fig. 13)

1b. Clasper spatula-type, depressed dorso-ventrally, with pointed distal tip; glans

clasper always composed externally of six components, namely, rhipidion, slit, sentinel, spike, shield and dike, and internally, composed usually of eight cartilage elements except for species U having ten elements, namely, axial cartilage (ax.), dorsal and ventral marginals (d.mg. and v.mg.), three dorsal terminals (d.tr. 1, 2 and 3), and two or four accessory terminals (a.tr. 1, 2, 3 and 4); (Figs. 5—7 and 14—19) ..... *Raja*

14a. Spike hooked or blunt posteriorly; sentinel slender or extremely large; anterior arms of accessory terminal 1 asymmetrical.

15a. Rhipidion markedly developed in monolobe; dike ill-defined or obscure; anterior arms of accessory terminal 1 markedly asymmetrical or leaving only the left arm, and the posterior arm slender or otherwise remarkably developed in axe-like projection.

16a. Type 11: Shield moderately large; sentinel growing in a slender projection (Type-St[1]); spike small, peeping out from a pocket lying under the sentinel (Type-Sk[1]); posterior projections of both accessory terminals lacking bifurcation, elongated into subequal length (Type-At[a]) ..... *R. tengu* (T in Figs. 6 and 19)

16b. Shield remarkably developed in large size; sentinel inconspicuous, lying with spike bearing hook, if sentinel is large, spike is very obscure, attached to sentinel; posterior projection of both accessory terminals specialized in more or less extent.

17a. Type 12: A large slit present; sentinel very large (Type-St[4]); spike obscure (Type-Sk[1]); dorsal terminal 1 large and polygonal in shape (Type-Dt[d]); ventral terminal represented by Type-Vt[f]; accessory terminal highly specialized (Type-At[f]) ..... *R. pulchra* (U in Figs. 6 and 19)

17b. Type 13: Two or three slits present; sentinel usually not distinct (Type-St[1]); spike apparent, hooked posteriorly (Type-Sk[3]); dorsal terminal 1 represented by Type-Dt[c]; ventral terminal with Type-Vt[e]; accessory terminal with Type-At[b].

18a. Spike slightly hooked posteriorly, so that the posterior projection of accessory terminal 2 not so markedly hooked ..... *R. macrocauda* (V in Figs. 6 and 19)

18b. Spike strongly hooked posteriorly, so that posterior projection of accessory terminal 2 deeply hooked, projecting beyond distal tip of accessory terminal 1 ..... *R. gigas* (W in Figs. 6 and 19)

15b. Type 8: Rhipidion usually well-developed in bilobes; dike moderately large; anterior arms of accessory terminal 1 less symmetrical, and the posterior arm slender; posterior projection of accessory terminal 2 hooked (Type-At[b]) ..... *R. kenojei* (M in Figs. 5 and 17)

14b. Spike usually pointed or slightly hooked posteriorly; sentinel bulge developed, covered by fleshy skin; dike clearly seen; anterior arms of accessory terminal 1 usually symmetrical except

for species O (*hollandi*).

19a. Type 9: Sentinel devoid of keen edge posteriorly (Type-St^2), so that the posterior arm of accessory terminal 1 broadened; dorsal terminal 1 broad (Type-Dt^a) or tapering off (Type-Dt^e).

20a. Rhipidion bilobed; spike poorly marked as a small spine lying under large sentinel; dorsal terminal 1 with type-Dt^a; anterior arms of accessory terminal less symmetrical, and the posterior arm pointed ..... *R. acutispina* (**N** in Figs. 5 and 17)

20b. Rhipidion monolobed, but if bilobed, spike distinct, sticking out under sentinel; anterior arms of accessory terminal 1 almost symmetrical.

21a. Rhipidion well-developed with monolobe; spike obsolete; dike elongated posteriorly to symphysis of the two lobes of glans clasper; dorsal terminal 1 narrower as in Type-Dt^b (Q in Fig. 15).

22a. Spike somewhat short peeping out from under sentinel (Q in Fig. 5), so that posterior projection of accessory terminal 2 elongates posteriorly as long as the accessory terminal 1 ..... *R. porosa meerdervoorti* (Q in Figs. 5 and 18)

22b. Spike long, thrusting out from under sentinel (Q′ in Fig. 5), so that posterior projection of accessory terminal 2 elongated posteriorly beyond distal tip of the accessory terminal 1 .... *R. porosa tobae* (Q′ in Figs. 5 and 18)

21b. Rhipidion moderate in size with monolobe or bilobes; spike more or less hooked posteriorly, projecting posteriorly beyond distal tip of sentinel; dike well-developed, elongating posteriorly to the symphysis of two lobes; dorsal terminal 1 broad or narrow.

23a. Rhipidion bilobed; two slit present; spike slighly hooked, well-stuck out beyond distal tip of sentinel; dorsal terminal 1 less tapering off (**R** in Fig. 14); posterior arm of accessory terminal 1 rather slender; posterior projection of accessory terminal 2 crooked and hooked distally with sharply pointed tip (Type-At^c) ..... *R. fusca* (R in Figs. 5 and 18)

23b. Rhipidion monolobed; only one slit present; spike slightly stuck out from distal end of sentinel; dorsal terminal 1 broad (Type-Dt^b); posterior arm of accessory terminal 1 thickened; posterior projection of accessory terminal 2 slightly crooked and hooked distally with pointed tip ..... *R. schmidti* (**S** in

Figs. 5 and 18)

19b. Type 10: Sentinel furnished with keen edge (Type-St[3]) so that posterior arm of accessory terminal 1 broadened with knife-like margin; dorsal terminal 1 broad but heteromorphic.

24a. Rhipidion monolobed; sentinel distinct; spike obscure, hidden under the sentinel; a large slit present; dorsal terminal 1 polygonal in shape (Type-Dt[d]; O in Fig. 14); left arm of accessory terminal 1 greatly elongated; attachment of accessory terminal 2 thickened instead of posterior projection of the element being shortened .... *R. hollandi* (O in Figs. 5 and 17)

24b. Rhipidion bilobed; sentinel moderately developed with keen edge; spike remarkably long, elongated posteriorly to symphysis of the two lobes of glans clasper; two slits present; dorsal terminal 1 broad (Type-Dt[a]; P in Fig. 14); anterior arms of accessory terminal 1 symmetrical; attachment of accessory terminal 2 rather large, and the posterior projection greatly elongated posteriorly..... *R. macrophthalma* (P in Figs. 5 and 17)

(3). Interrelationships of the Japanese rajids supposed from structural evidence of the clasper:

Differences as well as modes of differentiation in the features of the clasper of rajid fishes are too complex and diversed for us to give those characteristics of each form in the compact system. In other words, it is almost impossible to show them exactly *en bloc*. But, it may be said, on the whole, from the foregoing descriptions and comparisons that noteworthy interspecific differences and genealogical trends have been found in the following characters: i) presence or absence of the pseudosiphon, and degree of development and location of the component, if present; ii) presence or absence of the spur or the spike, and the degree of development, if present, of the components, and iii) form of the knife or the sentinel, and the degree of development of the components, if present, and their associated internal features, such as: (i) form and location of the dorsal terminals, (ii) form of the ventral terminal, (iii) mode of development of the accessory terminals, and (iv) other structural elements marked as worthy for the consideration in view of arriving at a conclusion.

To interpret such differentiations in the suppositional noteworthy characteristics as are mentioned above in several categories, the present writer has arranged the following Table 4, where external and internal characteristics are assorted into thirteen types so as to serve as the characteristics of the respective types of the organ.

ℓ. **The Pseudosiphon related to the features of the dorsal terminal 1** :- As already described in the preceding paragraph, the pseudosiphon in the organ of the northern form of Japanese rajids is assorted into three types (Ps^1, Ps^2 and Ps^3) based on the degree of development and the location of the component, but it disappears in

Table 4. Comparison of important characteristics of the claspers of Japanese rajids, based on their thirteen types of the organ assorted. + or — sign represents presence or absence of the components. For abbreviations, see text.

Characters	Types												
	1	2	3	4	5	6	7	8	9	10	11	12	13
External:													
pseudosiphon (Ps)	Ps^1	Ps^1	—	Ps^2	—	Ps^1	Ps^3				—	-	-
knife (Kn) or sentinel (St)	—	Kn	Kn	—	—	—	—	St^1	St^2	St^3	St^3	St^4	St^1
spur (Sp) or spike (Sk)	—	—	—	Sp^2	Sp^1	Sp^1;—	Sp^3	Sk^3	$Sk^{1;3}$	$Sk^{1;2}$	Sk^1	Sk^1	Sk^3
rhipidion (Rh) and shield	—;—	—;—	—;—	—;—	—;—	—;—	—;—	+;+	+;+	+;+	+;+	+;+	+;+
Internal:													
axial cartilage (Ax)	Ax^1	Ax^1	Ax^1	Ax^1	Ax^2	Ax^1	Ax^3	Ax^a	Ax^a	$Ax^{a;b}$	Ax^a	Ax^a	Ax^a
dorsal terminal (Dt)	Dt^K	$Dt^{J;L}$	Dt^A	Dt^B	$Dt^{C;D}$	$Dt^{E;F;G}$	$Dt^{H;I}$	Dt^a	$Dt^{a;b}$	$Dt^{a;d}$	Dt^a	Dt^d	Dt^c
ventral terminal (Vt)	Vt^1	$Vt^{2;4}$	Vt^3	Vt^4	Vt^3	$Vt^{4;5}$	Vt^4	Vt^a	$Vt^{a;b;c}$	$Vt^{b;c}$	Vt^d	Vt^f	Vt^e
accessory terminals (At)	At^1	At^4	At^5	At^1	At^6	$At^{1;3}$	At^2	At^a	$At^{d;e}$	$At^{d;e}$	At^a	At^f	At^b
Genera	*Rinoraja*		*Breviraja*						*Raja*				
Species	K	J;L	A	B	C;D	E;F G	H;I	M	N;Q R;S	O;P	T	U	V;W

the organs of certain species of the northern form and of the whole members of the southern form. These facts are of primary importance for our studying the genealogical modifications of the organ.

As to the examination and the comparison of the pseudosiphon found in Japanese rajids, the present writer has presumed that the pseudosiphon should have its name in conformity to genealogical relation to the structural features of the clasper in order to be given its compact meaning of the component. This concept concerns the present scheme a great deal because it is suggestive of the relationship in the organs and has great difficulty in our selecting the significance of characters which the organs have.

Thus, the writer has fixed his attention on the following so as to give a reasonable explanation to the present question; (i) as has been repeated in the foregoing description and comparison, the pseudosiphon is developed in different manners in the glans clasper of the northern form, the organ of which is classified into three types. Moreover, in these types the pseudosiphon occupies its position underlying the dorsal terminal 1, or is in close relation to the degree of development of the cartilage. Therefore, in naming and comparing the degree of development of the pseudosiphon, we can reasonably consider that the features of these two components have changed in close relation to the differentiation of the glans clasper; (ii) on the contrary the pseudosiphon in the organ of *Rhinobatos schlegeli* (Fig. 20 **a**) is markedly developed, found on the inner side of the dorsal border of the glans clasper (since the clasper is dorsal aspect in the Fig. 20), though the component was regarded as a 'slit' by LEIGH-SHARPE (l.c.). However, the dorsal terminal 1 of the guitarfish is highly excellent in its size by having broad, complete outline, and by being located along the ventral side of the glans, and the room which is the pseudosiphon itself is consequently inserted much to ventral side of the clasper. This relation between the position of the pseudosiphon and that of the dorsal terminal 1 observed in the organ of a thornback (*Platyrhina*

sinensis) is more advanced than in the guitarfish. Namely, the pseudosiphon in the thornback is developed in a large fissure, wholly inserted to the ventral side of the glans, underlying the broad dorsal terminal 1 (Fig. 20).

Such being the case, the present writer is inclined to believe in all probability that the pseudosiphon in the rajids much have gradually shifted to the dorsal border from the ventral of the glans, as is the case with the guitarfish. More exactly, the structural pattern in the glans claspers of the rajids may have changed in congruity with outward twisting capable of turning over the portion, resulting in the differentiation and transmigration of the pseudosiphon together with the dorsal terminal 1. If this view is justifiable, the genealogical trends in the structural pattern in the glans claspers of the rajids may naturally be assumed. That is to say, the pseudosiphon and the dorsal terminal 1 found in the species K may be the most primitive, as these components closely resemble those of the guitarfish. Taking this into consideration, the trend of differentiation of the pseudosiphon can be traced in order from Type-Ps^1 to -Ps^2 and -Ps^3. However, the manner of differentiation of the dorsal terminal 1 seems to be more complex, being in convergence and divergence with changes of the structural pattern in the glans, though each form of the component has great value for taxonomic basis. At any rate, it is very probable that the more specialized organ the species has, the greater degree of differentiation is found in the features of the pseudosiphon and the dorsal terminal 1. Further, this fact that certain species in the northern form and the whole species of the southern form have no pseudosiphon with markedly degenerated dorsal terminal 1 may be justified when we consider that they are offshoots from their ancestral forms in which the pseudosiphon has already disappeared. In this case, therefore, the linealogical trend may be presumed only from the transformation in the dorsal terminal 1.

The consideration on the differentiation of the other terminal components developed in the glans are given below.

§§. **Relationships of the organ classified into thirteen types :-** That general structure in the clasper indicates remarkable difference between the two major forms as has already been noticed. Of the seven types belonging to the northern form, Type 1, to which only the species K is referred, may be the most primitive in having a large pseudosiphon associated with unspecialized dorsal terminal 1. But it is interesting to note that species is found a large funnel, which may be a specialized feature. Presence of large dorsal terminal 2 followed by a small dorsal terminal 3, and J-shaped ventral terminal are also thought to be primitive features, because these elements have close affinity with those found in the guitarfish.

Type 2, may be nearest to the preceding, but it is more highly specialized than the latter in the following points: both dorsal and ventral terminals are somewhat reduced in size, and the accessory terminal is markedly specialized to form the knife associated with the claw, which is modified from distal portion of the ventral terminal. By comparing these characteristics in the two species involved in this type, the species L may be more specialized than the species J, in having more reduced dorsal terminal 1 and ventral terminal, compared with those in the latter.

Type 3, which is represented by only one species A, seems to be an intermediate in structure, resembling partly the preceding type and partly the following one, in having much smaller dorsal terminal 1 without the pseudosiphon, somewhat reduced ventral terminal, and specialized accessory terminals which form the knife of the ventral lobe. The pent in external and the accessory terminal 2 are considered to be special features in this type.

Type 4, which is represented but one species **B**, may be transitional phase between Types 2 and 5, in having the reduced pseudosiphon located on marginal portion of the dorsal lobe of glans clasper and having the dorsal terminal 1 somewhat similar to that of Type 2. But, the present species is distinct from any other relatives in some characteristics of such components as the dorsal terminal 2 and 3, and the accessory terminal.

Type 5, may be taken as the most specialized phase within the northern form, and is exemplified by the two species **C** and **D**, whose organs are marked from those of any other relatives in the following points; presence of large funnel and the spur, and absence of the pseudosiphon associated with greatly degenerated dorsal terminal 1. In spite of these specialized features thus noticed in both external and internal of the glans clasper, the two species involved in this type are quite distinguishable each other in the following respects, viz., the dorsal terminal 1 and the ventral terminal of the species **D** are thought to have more specialized features than those of the species **C**, but the features found in the accessory terminal and the distal part of the ventral marginal seem to be in reverse relation between the two species. On the basis of these characteristics the species **D** may be, on the whole, more specialized than the species **C**, which is linked partly with the species **A** on one hand and partly with the species **B** on the other.

Type 6, involving the three species **E**, **F** and **G** may be related partly to Types 1 and 2, because these species are characterized by having more or less reduced pseudosiphon located on dorsal border of the glans clasper. But this type is discriminated from its relatives in the following features in the organ, i.e. the dorsal terminal 1 and the ventral terminal are the most attractive in the organ of this type. Though the pseudosiphon is distinct and the general structure of the organ is in common in these three species, they can be clearly distinguished from each other according to their differentiations in the organ. These apparent diversifications which presumably may serve for the consideration in question are; differences in size and location of the pseudosiphon, degree of development of the funnel, presence or absence of the spur, and features of both dorsal terminal 1 and ventral terminal. In comparison with these features the species **F** seems to be the most primitive in this group. But the other two examples may have sprung from the common ancestor in their own way. The fact that the species has some phyletic affinity with the species **K**, **J** and **L** may be owing to the deep sea where the species **F** is found.

Type 7, involving three forms **H**, **I** and **I′** seems to be far apart in the degree of differentiation from any other types mentioned above, and it is rather difficult to determine the relationship between them based on the characteristics of the organ. But, it appears to me that this type may be somewhat nearer to Type 4 at least in having further degenerated pseudosiphon followed by the ridge covering the inner surface of the dorsal lobe, and in having the dorsal terminal 1 and the ventral terminal similar to those found in the species **B**. When the characteristics of the three examples in this type are compared, the species **H** is distinct from the two subspecies **I** and **I′**, the species **H** may be regarded as a less specialized form of the organ because the degree of outward twisting in the glans clasper of the species **H** is considered less. The organ of the species **H** has simpler external feature than the organs of the other relatives. On the other hand, the organs of the two subspecies have a singular character in having the scales developed on the dorsal lobe of the glans. It may be said that the presence of the scales, however, is of unique feature in the organs of the two forms. On the whole, the subspecies **I** seems to be linked more with the species **H** than the

subspecies I′ in their features of the organ, especially in the accessory terminal.

With regard to the general feature of the organ of the southern form, two phyletic series are assorted on the basis of structural evidence, such as species M-stem and species T-stem. The M-stem contains the three types of organ, ranging from Types 8 to 10, and the T-stem covers from Types 11 to 13.

Type 8, which involves only one species M, represents the most generalized features of the organ of the three types under the M-stem, in having the following character; the sentinel is less developed in Type-St[1], the dike is moderately developed, the dorsal terminal 1 is broad with Type-Dt[a], and the accessory terminals are moderate in development with no sharp edge with Type-At[b]. This type of the organ seems to be related partly to Type 9 and partly to Type 11, in their characteristics of the organs.

Type 9, is exemplified by the four forms, N, Q (Q′), R and S, and is nearest to the preceding, but the present type is more specialized than the preceding at least in the following features; the sentinel is broad with Type-St[2], the dike is distinct, and the accessory terminals are thickened. In comparing differentiation of the dorsal tarminal 1, we can surely believe that the two forms Q (Q′) and R may be distinguished from the other two species N and S, in having the element with tape-like shape (Type-Dt[b]), while the latter two have broad dorsal terminal 1 (Type-Dt[a]) like that of the species M. Such being the case, the species Q (Q′) seems to have the most specialized feature in this type in respect to the cartilage, and may be contiguous to the species R. Moreover, the species Q (Q′) can be clearly distinguished from the species R in having the posterior arm of the accessory terminal 1 more thickened than that of the latter (cf. Fig. 16). It is apparent that the group involving the two species N and S may have originated in the common ancestor of the species like M, because these species have rather similar elemental structures. Further, it should be noticed that the two subspecies Q and Q′ are closely related each other to the structure of the organ, but the two are different from each other in the feature of the accessory terminals, as has been noticed (p. 8). This subspecific difference in the organ can also be seen when we compare the organ of the subspecies Q with that of a form which often has peculiar color pattern as found in *Raja katsukii*. By the way, TANAKA (1916) added *Raja katsukii* to Japanese for the first time. Hence, *Raja katsukii* is identical with the subspecies Q on the basis of their structural components of the organ (cf. Figs. 5, 18 and Pl. II).

Type 10, seems to involve two specialized examples, O and P, which are different each other in the features of some components of the organ. The species P, on the other hand, may be more closely related to the two species N and R than the species O, in having similar dorsal terminal 1 (Type-Dt[a]) and the accessory terminal 1, which are highly specialized in the species O (cf. Figs. 14, 16).

Type 11, is modeled after the characteristics of the organ of species T, which seems to have the most generalized feature of the organ in this phyletic series, in having the dorsal terminal 1 of Type-Dt[a], the accessory terminals of Type-At[a], and the ventral terminal with unspecialized posterior portion. On the basis of these characteristics we can see close relation between the organ of the present species and that of the species M (cf. Figs. 14—16).

Type 12, which involves only one species U, seems to be more highly specialized than the preceding or the following types, in having many noteworthy features in the organ, as has been mentioned in the preceding paragraph.

Type 13, is exemplified by the two deep-sea forms, V and W, and is nearer to

Type 11 than to Type 12, as it has a broadly developed dorsal terminal 1 (Type-Dt^c), and very asymmetric anterior arms of the accessory terminal 1. But the present type seems to be more specialized than the Type 11 at least in having the accessory terminal 2 which is furnished posteriorly with the hook and the attachment (cf. Fig. 16). On the basis of these characteristics of the elements, the species **W** may be said to be in a more advanced condition than the species **V**.

The writer firmly believes that the organ of the species **T** may have originated from an ancestral form, from which such two diversifications as represented in Types 12 and 13 may have sprung in different directions in the specialization of the organ. It is very interesting to note that the present hypothesis is also justifiable in the other different characteristics of both external and internal features found in these species, as has already been noticed by the present writer (1955, p. 50).

(4) **Relation between the Rajidae and allied families of the batoids, suppossed from the features found in the claspers and its associatd organs:**

As to the origin of the Rajidae, it is a general opinion that the family, either the Rhinobatidae or the Platyrhinidae, is most closely related to this family because many features in these groups have something in common with each other. In the author's recent view on this problem in reference to Japanese rajids (ISHIYAMA, 1952, p. 7), a conception has been based on the fact that the fish referable to the genus *Rhinobatos* whose characteristics in the rostrum probably approximate most closely to the fish referred to the genus *Raja*. And, this hypothesis has been precisely argued upon in the foregoing chapter of the present investigation.

In order to emphasize the same point of view, the author has found it necessary to demonstrate some noteworthy facts found in the male organs of these groups related to the Rajidae, and determined which of these families is more closely related to the Rajidae in question, for this is the main function of the present chapter. Discussions are conveniently given in two ways; first on the external features and then on the internal features of the organs.

With regard to the external characters, LEIGH-SHARPE (op. cit.) stated on the form of the clasper in the Batoidei as "the claspers are stout, not denticled, bivalve, and expansible, except in the Rhinobatidae." This statement, however, must be corrected so far as dentition is concerned, inasmuch as the organs of certain species in our rajids are furnished with minute placoid scales, as has been described in the foregoing chapter. Therefore, this feature is not unique to the organs in the Rhinobatidae and the Platyrhinidae, and besides, such feature as the dentition of the organ may provide a sound basis for assuming that there may be some relation between the two related families and the Rajidae. Further, the fact that the degree of dentition in the organ is much less in the *Rhinobatos* than in the *Platyrhina*, as shown in the Fig. 20, may be a safe assumption that the evolutional course may have occurred through the Rhinobatidae from the Platyrhinidae to the Rajidae, so far as the feature in question is concerned. On the other hand, the glans clasper of the Rajidae is remarkably expansible when it is in erection. This phenomenon is not seen either in Rhinobatidae or in Platyrhinidae, because the structural pattern of the glans clasper in these two allied families is not so much twisted outward as in rajids. This fact may have some causal relation to the transformation of the pseudosiphon, as already mentioned (p. 38). Namely, the pseudosiphon is remarkably developed, inserted to ventral side in the *Platyrhina*, and it is relatively reduced, shifted partly to dorsal side in the *Rhinobatos* (Fig. 20**a**), but it is less developed on dorsal side or is disappearing in the Rajidae.

Judging from these noteworthy evidences mentioned above, the present writer surely believes that the Rhinobatidae is more closely related to the Rajidae than to the Platyrhinidae, so far as the external features of their claspers are concerned.

Turning to the internal features of the organ, the writer has drawn his attention especially the following two points: i) features of the cartilages composed of the clasper, and ii) degree of development of both clasper siphon and clasper gland.

The cartilages of the clasper are characteristically much more complex in the rajids than in *Rhinobatos* and *Platyrhina*. But, as shown in Fig. 20 a″, a‴, b′, b″, the *Rhinobatos* has its features in the cartilages with general approach to the Rajidae, especially in the northern form of our rajids, at least in having the dorsal terminal with smooth margin, and the ventral terminal with hook, both of which are somewhat related to those of the species K (cf. Figs. 10 and 11). On the other hand, the difference

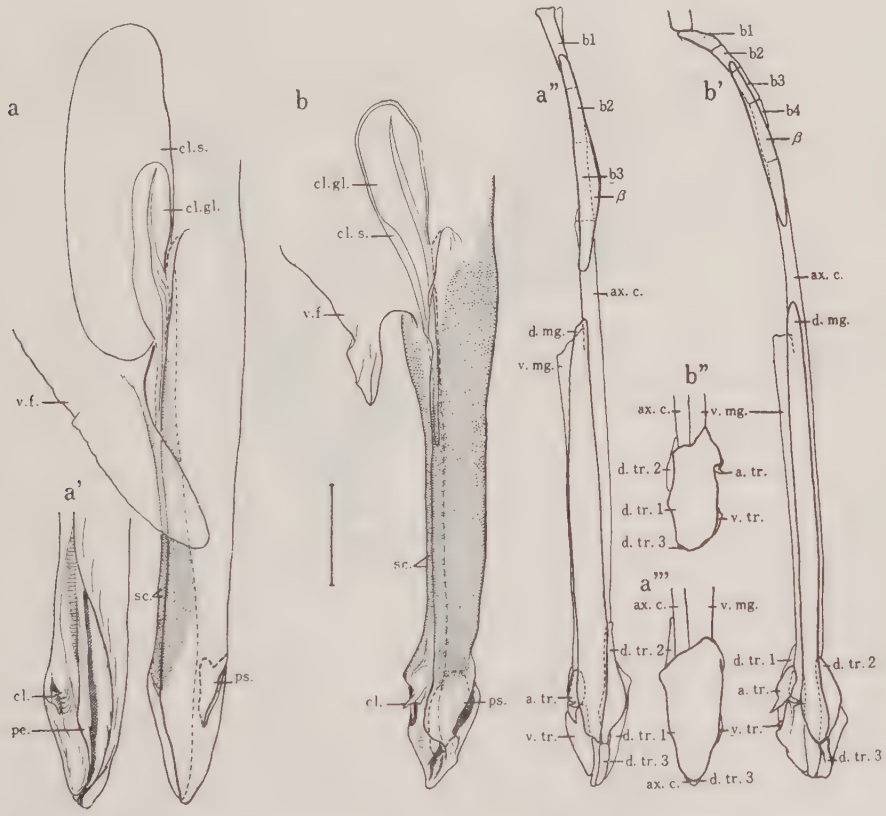

Fig. 20. Comparison of external and internal features of the claspers and associated organ of *Rhinobatos schlegeli*, a — a‴, and *Platyrhina sinensis*, b — b″. a and b, dorsal aspects of the clasper and the clasper siphon dissected; a′, glans clasper when opened; a″ and b′, dorsal aspects of the cartilages of the organs; a‴ and b″, ventral aspects of the cartilages of the glans claspers. Abbreviations in external (a, a′ and b) are; cl., claw; cl. s., clasper siphon sac; cl. gl., clasper gland; pe., pera; ps., pseudosiphon; v. f., ventral fin; sc., scales which are stippling; and internal (a″, a‴, b′ and b″); ax. c., axial cartilage; a. tr., accessory terminal; b_{1-4}, basal segments; β, beta cartilage; d. mg. and v. mg., dorsal and ventral marginal, respectively; d. tr. 1 — 3 and v. tr., dorsal terminal 1 — 3 and ventral terminal, respectively. Accompanying scales, 1 cm.

of these cartilages between the Rajidae and the Platyrhinidae is greater than between the rajids and the rhinobatids. Further, the difference in the number of the basal segments is worthy of being noticed in the three families. Namely, three

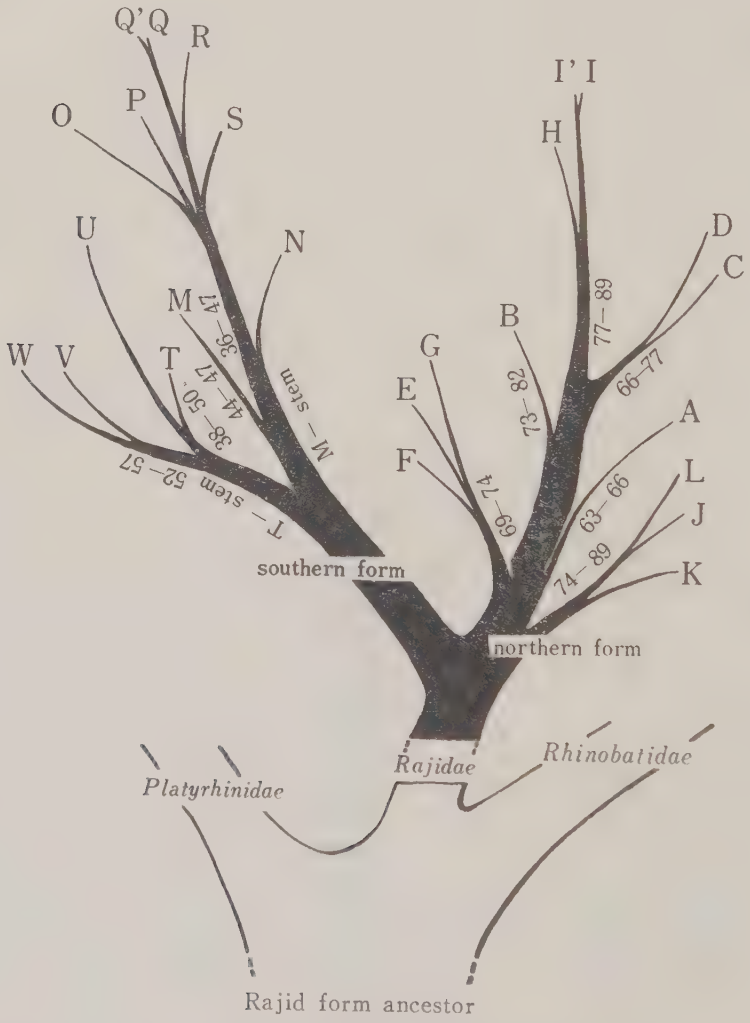

Fig. 21. Suggested interrelationships among the species of Japanese rajids, and between the Rajidae and its allied families, supposed from those structural features in the male organs (clasper and its associated apparatus), and the number of precaudal vertebrae of the rajids. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*; I', *B. smirnovi ankasube*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*; M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q, *R. porosa meerdervoorti*; Q', *R. porosa tobae*; R, *R. fusca*; S, *R. schmidti*; T, *R. tengu*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*.

intermediate segments (b_{1-3}) are present in the *Rhinobatos*, instead of four segments (b_{1-4}) in the *Platyrhina*, but two cartilages are always present, in the Rajidae, so far as the writer's knowledge is concerned. Should these relations on the number of the basal segments be correct, the Rhinobatidae may be intermediate between the Rajidae and the Platyrhinidae.

Concerning the clasper siphon and the clasper gland in the batoid fishes, LEIGH-SHARPE (op. cit.) made the following conclusion: "Those, the clasper gland of which has been developed inside the original siphon sac--*Lamna*, *Rhina* and *Batoidei*." And, he further defined the organ of the Batoidei, thus, "The siphon sac always contains a groove, albumen gland confined to the dorsal side of the sac." It is worthy of a special mention that finding of different degrees of development in the clasper gland in the clasper siphon are revealed by the three families. Namely, in the rajid fishes, both organs are markedly developed, and besides, the clasper gland occupies the whole room of the large clasper siphon sac. Whereas, in the *Rhinobatos* the clasper gland is rather small in size, occupying only a part of the space enclosed in the clasper siphon which is relatively as large as that of the rajids. Further, in the *Platyrhina*, both components are less developed, where the gland is small in size, as compared with those in the preceding filling the space ensphering the small clasper siphon. When we consider the fact thus obtained by comparing the degrees of development of the two components, the clasper siphon and the clasper gland which have been revealed among the three representatives in the batoid fishes, we can naturally suppose that the Rajidae has closer relation to the Rhinobatidae than to the Platyrhinidae.

Conclusively, should these studies of the differentiations given from the morphological features of the claspers and its associated organs be accepted and justifiable, the phylogenical relationships in Japanese rajid fishes, and between the Rajidae and its allied families may diagrammatically be illustrated in the foregoing figure (Fig. 21).

The present writer can make some noteworthy remarks on this figure: i) a rajid fish may have arisen from an ancestor like a rhinobatid, ii) the so-called northern form of Japanese rajids may have originated from that ancestral stock, iii) the newborn which resemble the genus *Breviraja* may have again branched in two new forms like the so-called southern form, the genus *Raja*, and the genus *Rhinoraja*, iv) of these two new offshoots the genus *Raja* may have originated deeper in phylogeny than the genus *Rhinoraja*, and v) variation in vertebral count in each group of species can be considered corresponding with the phylogenetic progression along each branch.

b. Egg-capsule

As regard to the egg-capsules of Japanese rajids the present writer has given a revisional study*) by using many specimens referable to 21 species and two subspecies. Therefore, the writer described here merely those keys to species or group of species and summary which were quoted from the foregoing paper, and feature of the capsule in several forms will be given in the systematic part of this account for practical use.

(1) Key to egg-capsules:

1a. Very large in size, measuring more than 100 mm in length exclusive of horns.
2a. Surface very rough being velvety in texture, Group Eg^1.

* Observations on the egg-capsules of skates of the family Rajidae, found in Japan and its adjacent waters. Bull. Mus. Comparative Zool., 1958: Vol. 118, No. 1, pp. 1~24, 10 figs. The author's cordial thanks are due to Dr. Henry B. BIGELOW of the Museum of Comparative Zoology, Harvard University, and also to Mr. William C. SCHROEDER of the Woods Hole Oceanographic Institution, for reading the manuscript critically.

3a. Without strong fibroid hairs entirely covering the surface; prickles devoid of small stiff rods at their tips.

4a. Prickles rather long, being perpendicular to surface, Subgroup Eg^{1A}.

5a. Posterior horns longer than width of capsule; capsules 106 mm to 132 mm in length and 76 mm to 86 mm in width ..... *Breviraja isotrachys* (Fig. 61 $B_{4,5}$); *B. trachouros* (Fig. 62 $C_{4,5}$)

5b. Posterior horn shorter than width of capsule; length and width being from 106 mm to 120 mm and from 76 mm to 78 mm, respectively ..... *B. diplotaenia* (Fig. 64 $E_{4,5}$)

4b. Prickles very long, bending anteriorly, Subgroup Eg^{1B}.

6a. Capsule much larger than those of other northern forms, measuring from about 120 mm to 136 mm and from 73 mm to 90 mm in length and width, respectively; posterior horns longer than width of capsule; capsule-wall, exclusive of prickles, rather thin, being about 0.3 mm in thickness ..... *B. aleutica* (Fig. 67 $G_{5,6}$)

6b. Capsule smaller than those of the preceding, about 104 mm to 115 mm in length and from 69 mm to 80 mm in width; posterior horns almost equal to width of capsule; capsule-wall rather thick, measuring from about 0.5 mm to 0.6 mm in thickness exclusive of prickles ..... *Rhinorja kujiensis* (Fig. 72 $K_{4,5}$)

3b. Strong fibroid hairs entirely covering prickles, whick are densely furnished with small stiff rods at their tips, Subgroup Eg^{1C}; length and width of capsule being respectively from about 109 mm to 113 mm and from 65 mm to 67 mm; posterior horns longer than width of capsule; capsule-wall relatively thin, measuring about 0.2 mm in thickness exclusive of prickles ..... *B. matsubarai* (Fig. 65 $F_{4,5}$)

2b. Surface smooth or somewhat rough, without any velvety texture, Groups Eg^{2}, Eg^{6}, and Eg^{7}.

7a. Surface somewhat rough; horns tape-like in shape or reduced to rudiments, Groups H^{2}, H^{5}, and H^{6}.

8a. Horns rather long, growing slenderer toward tips, pointed at their tips, with a longitudinal slit located at their basal parts, Group H^{2}; capsule-wall composed of two layers, the outer one is furnished with many tubercles over the surface, Group Eg^{2}.

9a. Length and width of capsule about 150 mm and 90 mm, respectively; tubercles covering outermost layer sparsely developed with domed apexes, Subgroup Eg^{2A} ..... *B. smirnovi smirnovi* (Fig. 68 $I_{3,4}$)

9b. Length and width of capsule about 120 mm and 90 mm, respectively; the tubercles densely developed with ridged apexes, Subgroup Eg^{2B} ..... *B. parmifera* (Fig. 67 $H_{2,3}$)

8b. Horns very short or rudimentary, with a round opening located at their tips or at each of the four corners, Group H^{5} and H^{6}; capsule-wall composed of three layers, the outermost composed of many fibres running lengthwise in series, Group Eg^{7}.

10a. Horns very short, with the opening at their tips, Group H^{5}; broad notches present on lateral sides; length and width of capsule measuring from 140 mm to 185 mm and from 71 mm to 94 mm, respectively ..... *Raja pulchra* (Figs. 22 U and 83 U_4)

10b. Horns reduced to rudiments, with an opening at each of the four

corners, Group H^6; notches absent on sides; fibres composing outermost tissue less in diameter than those in 10a; the greatest in size of all capsules examined, measuring about 235 mm and 145 mm in length and width, respectively ..... *R. gigas* (Figs. 22 **W** and 86 W_3)

7b. Surface smooth; horns short, tube-like in shape, Group H^4.

11a. Length of capsule about 100 mm; capsule-wall very thick, measuring more than 1.0 mm, with a very thin pulpy layer which comprises about 13 % of the total thickness of the wall .... *R. tengu* (Fig. 82 T_3)

11b. Length of capsule about 130 mm to 140 mm; capsule-wall relatively thin, measuring about 0.4 mm, with a pulpy layer which comprises about 42 % of the total thickness of the wall .... *R. macrocauda* (Figs. 22 **V** and 85 V_4)

1b. Usually small in size, measuring less than 70 mm in length exclusive of horns.

12a. Horns long, whip-like in shape, bearing a longitudinal fissure; surface either rather rough or very smooth; Group H^1 and H^3.

13a. Surface rather rough, bearing minute trickles with ridged apexes; capsule-wall divisible into two thickened layers, beind compact in structure, Group Eg^3; moderate in size, measuring from about 57 mm to 68 mm and from 33 mm to 46 mm in length and width, respectively .... *Rh. odai* (Fig. 70 $J_{3,4}$); *Rh. longicauda* (Fig. 71 $L_{4,5}$)

13b. Surface smooth, without any sculpture; capsule-wall translucent, composed of two layers, the outer one very thin, instead of being relatively thick, the inner one parenchymatous in structure. Group Eg^1; very small in size, measuring about 38 mm and 22 mm in length and width, respectively ..... *B. tobitukai* (Fig. 60 $A_{5,6}$)

12b. Horns short, tube-like in shape, bearing a round opening at the tip, Group H^4.

14a. Capsule-wall composed of two layers, Group Eg^5.

15a. Capsule-wall about 0.25 mm thick; length and width of capsules measuring from about 51 mm to 57 mm and from 33 mm to 37 mm, respectively ..... *R. fusca* (Figs. 22 **R** and 80 R_7)

15b. Capsule-wall thin, about 0.15 mm thick; length and width of capsules about 43 mm to 59 mm and from 29 mm to 37 mm, respectively .... *R. porosa meerdervoorti* (Fig. 77 Q_3); *R. porosa tobae*

14b. Capsule-wall composed of three layers, Group Eg^6.

16a. Capsule-wall 0.25 mm to 0.4 mm, with a pulpy layer which is thinner than 50 % of the total thickness.

17a. Pulpy layer comprises about 20 % to 30 % of the total thickness of the wall; length and width of capsules measuring 56 mm to 66 mm and 34 mm to 37 mm, respectively; fibroid hair exceedingly well developed over the surface ..... *R. kenojei* (Figs. 22 **M** and 73 M_3)

17b. Pulpy layer comprises up to 50% of the total thickness of the wall, length and width of capsules measuring from 53 mm to 65 mm and from 27 mm to 39 mm, respectively... ..... *R. hollandi* (Figs. 22 **O** and 75 O_5);

R. schmidti (Fig. 22 S_4)

16b. Capsule-wall less than 0.2 mm in thickness, with a pulpy layer comprising as much as 60% of the total thickness of the wall.

18a. Capsules measure from 49 mm to 54 mm in length; surface densely covered with fine fibres .... *R. acutispina* (Figs. 22 N and 74 N_5)

18b. Capsule the smallest in size, measuring only from 39 mm to 42 mm in length; fine fibres covering the surface less developed than in 18a .... *R. macrophthalma* (Figs. 22 P and 76 P_4)

(2) Summary on egg-capsules:

i. Noteworthy features of the capsule were found in both the external and the histological structure. These characteristics include the shape, horns, fibroid tendrils and configuration of the external surface, and the structure of the capsule-wall, based on which following eight types of the capsules are classified (Table 5).

ii. In the so-called northern form, the capsule is characterized by having a long horn at each corner with a longitudinal respiratory fissure located midway near the tip of the horn, and having a rather simple structure of the capsule-wall (the tertiary egg-envelope) composed of two layers. The outer horny layer, however, assumes a highly specialized appearance, characteristic among different groups and species, having developed a definite form of armor on the surface that may serve a mechanical protection for the developing embryo in the low temperature of its environment.

iii. In the southern form, on the other hand, the capsule has a smooth surface

Table 5. Characters of the egg-capsules in Japanese rajid fishes classified into 8 types For abbreviated letters, see text.

Type	Horn, Group	Capsule-wall: configuration of surface	Capsule-wall: tissue	Group Eg and its Subgroup		Species and subspecies
1	H^1	smooth	2 layers	Eg^1	—	A
2	H^2	rather rough	2 layers	Eg^2	Eg^{2A}	I
					Eg^{2B}	H
3	H^3	rather rough	2 layers	Eg^3	—	J ; L
4	H^3	rough	2 layers	Eg^4	Eg^{4A}	B ; C ; E
					Eg^{4B}	G ; K
					Eg^{4C}	F
5	H^4	smooth	2 layers	Eg^5	—	Q ; Q' ; R
6	H^4	smooth	3 layers	Eg^6	—	M ; N ; O; P ; S ; T ; V
7	H^5	rather rough	3 layers	Eg^7	—	U
8	H^6	rather smooth	3 layers	Eg^7	—	W

and short horns which are usually perforated at the tip, and the wall shows a great variation not only in the inner layer but also, in some cases, in the outer one. Some are formed of only two layers, as is also true of the northern form, but the majority are characterized by having three layers, a pulpy layer being inserted between the two. A remarkable example of this is provided by the two species of *Raja* which produce an egg-capsule (Figs. 22 and 86; U, W) with highly specialized in both histological structure and external form. From all this evidence it

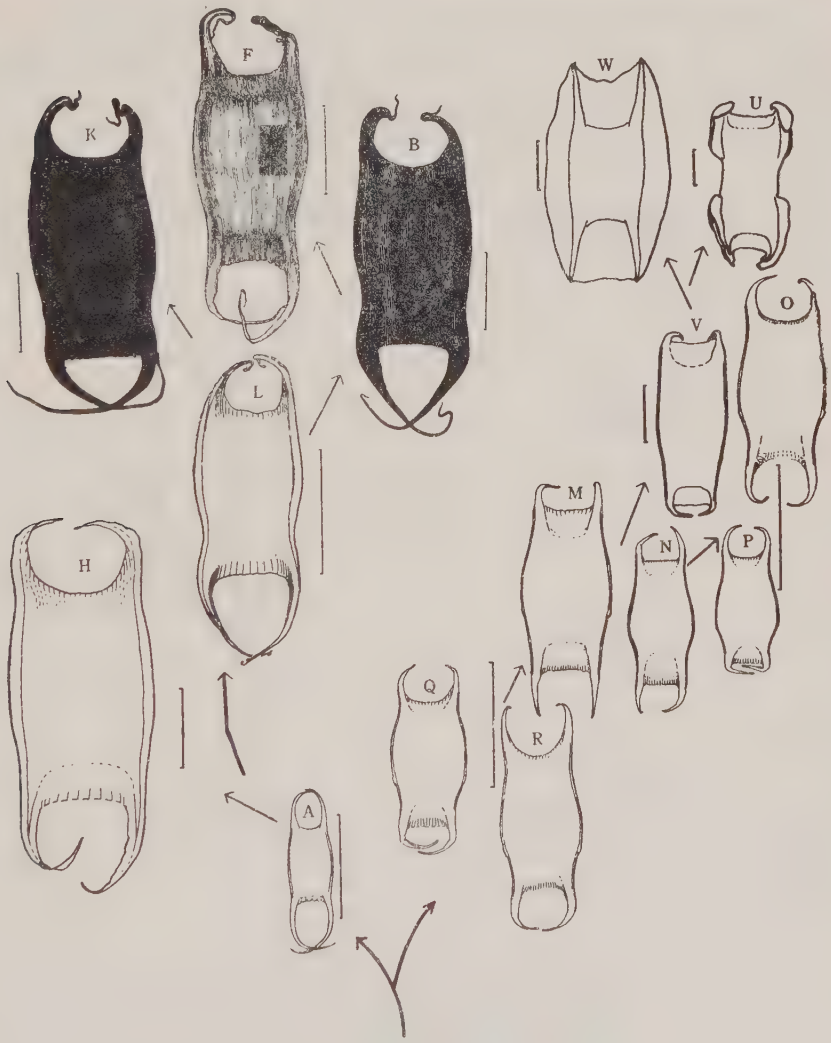

Fig. 22. Dorsal views of the egg-capsules, showing the probable phyletic relationships. As to the details of the surface configuration or of the structure of the capsule-wall, see Fig. given in each species. A, *Breviraja tobitukai*; B, *B. isotrachys*; F, *B. matsubarai*; H, *B. parmifera*; K, *B. Rhinoraja kujiensis*; L, *Rh. longicauda*; (northern form in the left series); M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q, *R. porosa meerdervoorti*; R, *R. fusca*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*; (southern form in the right series). Scales attached represent 5 cm.

seems conclusive that the external form and histological structure of the capsule case are important either mechanically or physiologically, or both, for the development of embryo which develops under relatively high temperature.

iv. This concept, based chiefly on the geographical distribution and the manner of breeding of the adult in relation to the features of the egg-capsules, of different groups and species, suggests that the divergence in pattern of these features have been due to environmental adaptation, in conformity with the two functional roles of the capsule.

v. Should this hypothesis be justifiable, successive changes in the features of the egg-capsules of Japanese rajids may be classified into 8 types (Table 5).

vi. These phenomena, an interesting instance of promorphological adaptive differentiation, foreshadow the general characteristics of the future embryo.

vii. This trend in the manner of differentiation within the capsules (Figs. 22 and 23)

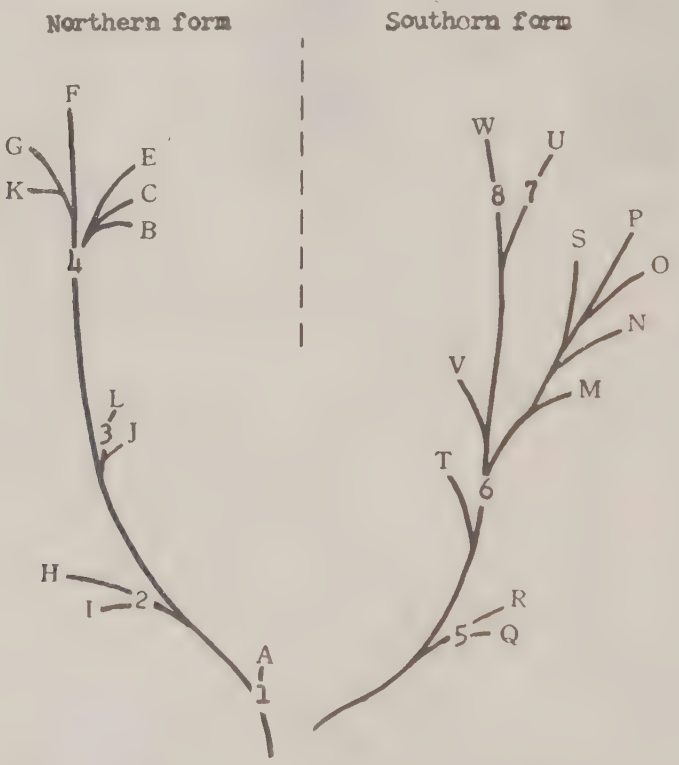

Fig. 23. Interrelationships of the egg-capsules of Japaneses rajids, supposed from both external and histological feature of the capsules, based on which 8 types were assorted. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda;* M, *Raja kenojei;* N, *R. acutispina;* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti;* R, *R. fusca;* S, *R. schmidti* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda,* W, *R. gigas.*

is related in the main to the phylogeny deduced from the claspers of this group of fish. From this fact it may be emphasized that the character of the capsule bears a significance of fundamental phylogenetic importance, though in some cases extreme accomodation to the conditions of the environment precludes an exact parallel between the two trends. Further, these evidences may make clear the general idea that the organ concerned with the reproduction of the animal is usually quite for the systematic classification of the animal.

C. Bearing of the external features of organs related to reproduction on systematics of the Rajidae

Regarding the organs of the male and the female sexes which serve to distinguish the species easily, the so-called rock-and-key relationship which goes by the name of the mechanical isolation today is not so much evaluated in the present day as before (Goldschmidt, 1940; Dobzahnsky, 1941). But, it has been known in some groups of fishes and animals that the organ of the male of one species is distinguishable from that of other species when it has complex features in the copulatory organs (Mayr et al., 1942; Uchida, 1955), such as, the penis in the Muridae (Tokuda, 1941) and in the xiphophorin fishes (Gordon and Rosen, 1951), the petasma in the penaeid shrimps (Kubo, 1949), and many insects having such organs. Thus, Hubbs and Turner (1938) laid stress on the conception; "it is quite in line with recent advance in the taxonomy of fishes, and of animals in general, to find again that the characters associated with reproduction provide the most reliable indication of relationship."

Evidently, the present author has recognized that the characteristics in the external male organ (clasper) of the Japanese rajids seem to give, as described above, the most reliable basis for the systematics of this group of fish, and stated some conceptions on the heading.

On the other hand, the writer has found several noteworthy facts in the external female organ (egg-capsule) of our rajids, and confirmed that the trend in the mannner of differentiation within the capsules is related in the main to the phylogeny deduced from the male organs of this group of fish. But, it must be noticed that an exact parallel between the two trends is precluded in some cases from extreme accomodation to the conditions of the environment where the egg was laid.

As the elasmobranchs bring about internal fertilization by means of the specialized copulatory organs which are thought to have direct relation in less degree to the physico-chemical condition of the environment, the external male organ seems to be more highly evaluated as a taxonomic character than such an organ of the female as the egg-capsule, which varies with different features due to adaptive differentiation as mentioned above, and also more than any of other external or internal organs of the fishes, except for internal character related to reproduction. However, we taxonomists would all desire in distinguishing species to find out the most reliable diagnostic character which has some feature easy of identification with but little variability, though it may be impossible to do so in any particular species in animals in general, since a good taxonomic character of a single species cannot be constant without the least variation. Therefore, there are two different extreme ways in making a taxonomic category for a given species, i.e. one is to use the most reliable diagnostic character, idealistic as it is so far if present, and the other is to deal with a number of characters with limited variability useful for separating species.

In the present study, the procedure similar to the former of the two stated above

is attempted by the writer as he has confirmed that the external male organ seems to have the most reliable basis for the systematics of Japanese rajids when he has compared the characteristics in the organ with those in other external and internal parts of the body, important for the taxonomy of the elasmobranchs in most cases.

It is a matter of great interest that trend of the variation in the number of vertebrae in the groups of the fish agrees well with that deduced from the male organs (Fig. 21).

B. Characters other than those related to reproduction

a. Snout, its external and internal features

1. Description in general

The feature of snout has generally been used in taxonomy of various groups of elasmobranchs. In fact, the features of both external and internal parts of the snout in rajids have served for one of the marks worthy for diagnosis of some groups. But it has frequently been noticed that the variation in external feature of the snout is rather extensive even in a single species. Accordingly, various features of the snout, such as shape, flexibility, angle, degree of undulation on both sides and relative length of the snout have been examined so as to clarify the variability of this organ. Some features of these, however, are variable, especially with the growth of the body and between the sexes, in some cases. In the present study, therefore, a good many specimens of each species were examined in both external and internal characters of the snout. Then, the writer has obtained some compact knowledge of the features of the snout which may be worth in our finding a clew in taxonomy of the rajids dealt here.

2. Description and comparison of the snout

1). **External:**

(1). **Outline of the snout:-** In most of the rajid fishes, the snout is triangular in shape, which is so highly modified as to be adapted for the bottom life. The marginal sides of the snout are undulated in some degree. Degrees of undulation along the margin from the tip of the snout to the angle of pectoral fin have been believed to be very important by several authors. But the feature varies so much with the growth of the body, and with the sexes. Generally, the degree of undulation becomes greater with the growth of the fish, and it is greater in the male than in the female. Further, these tendencies are more pronounced in the southern form than in the nothern one.

The difference in the angle of the snout has also been considered by various authors as one of the important features, viz., GÜNTHER (1887), GILBERT (1896), EVERMANN and GOLDSBOROUGH (1907), SOLDATOV and PAVLENKO (1915), TANAKA (1916, '26), JORDAN and HUBBS (1925), SCHMIDT (1931), FANG and WANG (1932), HIYAMA (1940), FOWLER (1941) and BIGELOW and SCHROEDER (1948). This character, however, bears little use as to make it appreciable a clear distinction in any species as well as genera, due to not only obscurity in its measurement but also to no small variation with growth of the body and between the sexes. In short, the angle of the snout is greater in the young and in the female than in the adult and in the male. These differences are in close relation to differential growth of the length of the snout. Accordingly, the degree of the angle and the undulation in the margin of the snout may act as a specific character, but it is generally taken as an index of general

external discrimination in some species.

The flexibility of the snout recognizable by external touch is one of the most attractive features in the snout, by which the two main stocks of our rajids can be separated (ISHIYAMA, 1952). This shall be discussed later on in combination with the internal character of the snout.

(2). **Proportion of the length of snout:-** The proportional measurement of the snout to various parts of the body, especially to the length of the head has usually served for taxonomic criterion of the fish. But, it should be noticed that this character usually tends to vary with age or sex even in the same species. As seen in Fig. 24 and Table 6, the proportional measurement of the snout to the length of the head in relation to the width of disc which is substituted for the standard dimension may show the following general tendencies; i) mode of ontogenic change in the relative length of the snout seems to differ to some extent between the northern and southern forms. To be more exact, the relative length changes in linear relation with the growth of the body in the northern form, but it is curvilinear in the southern form as in the case with the tail (cf. pp. 66 and Figs. 31 and 32); ii) sexual difference in

Table 6. Ratio of proportional measurement of snout measured in head-length in three stages of Japanese rajids. For abbreviations, see text.

Stage and ratio / Species	Juvenile		Adolescent				Adult			
			male		female		male		female	
	range	average	range	average	range	average	range	average	range	average
A	—	—	2.09—2.20	2.12	2.10—2.26	2.17	2.03—2.18	2.13	2.12—2.24	2.17
B	1.95—2.32	2.11	1.92—2.04	1.95	1.88—1.99	1.94	1.94—2.06	1.96	1.90—2.03	1.94
C	1.73—2.25	2.02	1.99—2.12	2.07	1.84—1.94	1.87	2.00—2.25	2.09	1.83—2.03	1.91
D	—	—	—	—	—	—	2.19—2.26	2.22	1.94—2.03	1.99
E	2.00—2.09	2.03	1.92—2.25	2.05	1.89—2.04	1.97	1.92—2.32	2.15	1.92—2.06	2.00
F	2.08—2.35	2.27	2.50—2.60	2.55	2.48—2.25	2.51	2.50—2.63	2.56	2.44—2.52	2.48
G	1.81—1.86	1.83	1.92—1.97	1.94	1.83—1.86	1.85	1.92—2.05	1.98	1.64—1.90	1.74
H	—	—	—	—	—	—	2.06	—	—	—
I	1.96—2.04	2.00	—	—	1.94—2.04	1.99	2.10—2.33	2.19	1.87—2.10	1.98
I′	1.96—2.08	2.01	1.87—2.07	1.90	1.90—2.01	1.97	2.08—2.30	2.19	1.91—2.30	2.05
J	-		2.23—2.31	2.28	2.10—2.31	2.16	2.39—2.61	2.48	2.15—2.20	2.18
K	2.23—2.50	2.32	2.03—2.58	2.22	2.08—2.37	2.22	2.26—2.30	2.28	2.11—2.45	2.26
L	2.52	—	1.89—2.48	2.30	2.27—2.39	2.29	2.33—2.68	2.46	2.24—2.38	2.31
M	1.86—2.70	1.92	1.94—2.20	2.08	1.74—2.04	1.95	2.11—2.35	2.23	2.00—2.09	2.03
N	1.82—1.95	1.89	1.84—2.00	1.92	1.76—1.97	1.86	2.06—2.27	2.12	1.74—2.06	1.93
O	1.81—1.90	1.98	1.84—2.00	1.93	1.82—1.94	1.87	1.88—2.13	2.02	1.80—1.94	1.89
P	1.90—2.00	1.96	1.89—2.12	1.99	1.87—2.11	1.97	2.05—2.65	2.17	1.84—2.14	1.99
Q	1.80—1.92	1.86	1.94—2.09	2.00	1.82—2.18	2.06	2.02—2.40	2.15	1.85—2.17	1.95
Q′	1.69—2.16	1.82	1.81	—	1.80—2.00	1.88	2.11—2.16	2.13	1.58—2.00	1.88
R	1.89—2.07	1.96	1.95—2.16	2.07	1.84—2.15	2.00	2.12—2.43	2.22	2.02—2.14	2.16
S	2.04—2.06	2.05	2.11—2.21	2.16	2.07—2.18	2.12	2.29—2.49	2.42	2.17—2.62	2.42
T	1.69—1.80	1.74	1.62—1.76	1.68	1.55—1.71	1.62	1.75	—	1.59—1.68	1.63
U	1.95—2.23	2.14	1.73—1.93	1.81	1.66—1.88	1.77	1.80—1.94	1.95	1.69—1.75	1.72
V	1.72—2.04	1.81	1.67—1.78	1.71	1.62—1.73	1.66	1.77—1.84	1.79	1.62—1.64	1.62
W	1.61—1.70	1.63	—	—	1.65—1.66	1.65	1.81—1.84	1.82	1.60—1.83	1.68

the relative length is rather obscure or negligible in the northern members, though apparent in the southern ones; and iii) in most cases, the snout is shorter (the ratio is greater) in the adult male than in the adult female in the southern form, and the similar tendencies are seen in the proportional length of tail.

The proportional length of the snout and its ontogenic trend seem to have no more than a specific importance to each species in the northern form, considering that the snout has a very complex structure. On the other hand, the trend in the southern form may represent not only specific feature but also generalogical significance owing to rather common structure in the snout, as is described later on.

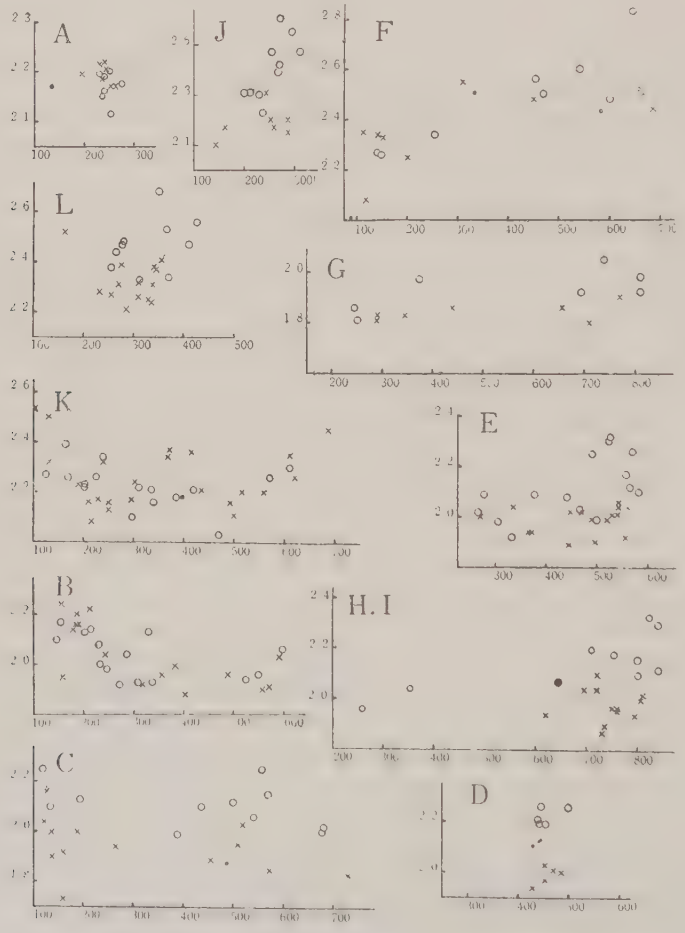

Fig. 24. Ratio of snout in length against head in relation to disc-width (in mm) in the northern form. Ratio, ordinate; disc-width, abscissa; circle, male; cross, female. Black spot represents the ratio in species H (*Breviraja parmifera*). A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; I, *B. smirnovi smirnovi*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*.

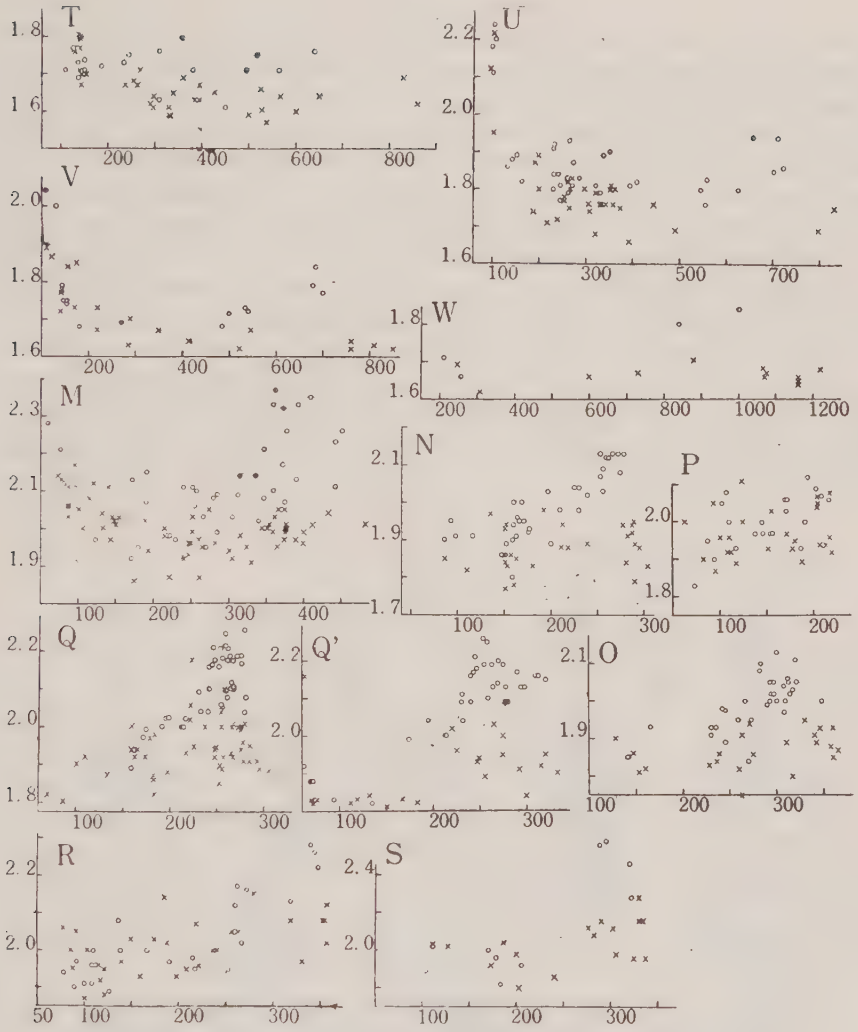

Fig. 25. Ratio of snout in length against head in relation to disc-width (in mm) in the southern form. Ratio, ordinate; disc-width, abscissa; circle, male; cross, female. M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q, *R. porosa meerdervoorti*; Q', *R. porosa tobae*; R, *R. fusca*; S, *R. schmidti*; T, *R. tengu*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*.

2). **Internal:**

Although anatomical characters of the snout have proved to be fundamentally important for our settling taxonomic criteria above the rank of genera of the Rajidae, the differences in principal features are important for distinguishing some related forms referred to the same genus. By principal features are meant the rostral cartilage and its appendices, the degree of forward extension of the pectoral fins on both sides and the shape of anterior fontanelle of the cranium.

(1). **Rostral cartilage and its appendices**:- In the Rajidae, the snout is generally supported internally by a cartilage with some degree of development that originally arises with forward prolongation of the skull. With regard to the feature of the

cartilage in rajid fishes a number of noteworthy works have already been done by several authors. The present writer has recently classified the Japanese rajids into three genera according to the characters of the rostral cartilage, agreeing with a view made by BIGELOW and SCHROEDER (1948). Namely, the so-called northern form which involves two genera is characterized by having a delicate rostral cartilage extending to the tip of the snout. The two genera are separated by the presence or absence of a basal segment developed at the base of the cartilage. In the southern form, on the contrary, the rostral cartilage is developed in a stout, rod-like projection caused by heavy calcification recognizable by external touch. Taking the feature of the cartilage into consideration, the Japanese rajids can be clearly assorted into three types, which are called herein Type S^A, S^B and S^C (Fig. 26), respectively, following the critiques mentioned above, viz.: Type S^A, which is referable to the species of the genus *Raja*, is characterized by having a stout, rod-like median bar without a basal segment (**W** in Fig. 26). Type S^B exemplified by species referred to the genus *Breviraja* is marked by a delicate rostral cartilage without a basal segment (**B** in Fig. 26).

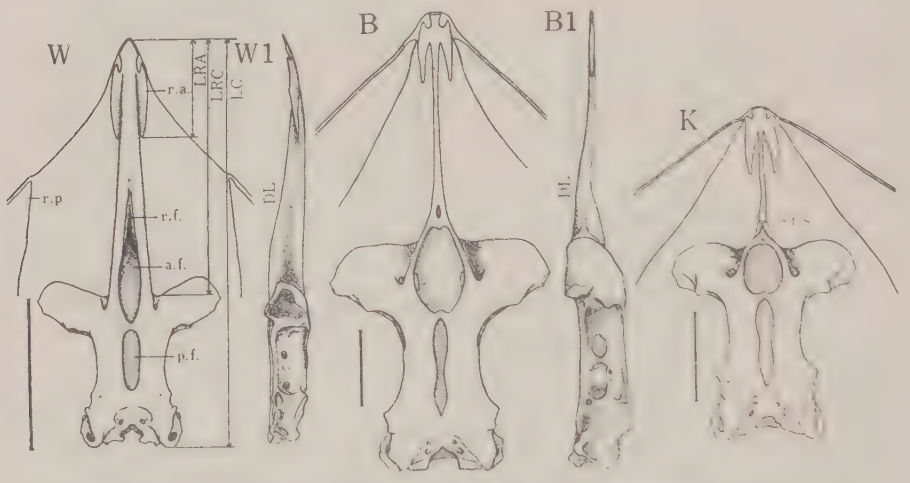

Fig. 26. Showing three types of the rostral cartilages of Japanese rajids, with the terminology and method of measurement. B, K and W, dorsal view; B_1 and W_1, side view; especially notifying the differences in degree of development of the rostral cartilage with or without the rostral segment and in shape of the rostral appendices. a.f. anterior fontanelle; DL, dorsal side; LC, length of cranium; LRC, length of rostral cartilage; LRA; length of rostral appendix; p.f., posterior fontanelle; r.a., rostral appendix; r.f. rostral fossa; r.p., radial cartilages of pectoral fin; r.s., rostral segment. B and B_1, *Breviraja isotrachys*; K, *Rhinoraja kujiensis*; W *and* W_1, *Raja gigas*. Scales represent 3 cm.

Type S^C is modeled after the characteristics of the cartilage observed in species of the genus *Rhinoraja*, whose rostral cartilage is developed with a basal segment at the base of the delicate cartilage (r.s. in Fig. 26 **K**).

At the distal part of the rostral cartilage a rostral appendix is attached on each side. Anterior tip of the rostral cartilage is inserted from a notch between the appendices. Feature of posterior portion of the appendix in relation to the rostral axis is very different between the northern and the southern forms. Namely, posterior end of the appendix fuses to or closely contacts with the side of the anterior part of rostral cartilage in the southern members without exception, but it is free in the

northern ones (ISHIYAMA, 1952). In either case, however, degree of development of the appendix sometimes differs so much in species specifically that it may act to serve as specific demarcation, or as linealogical consideration in some cases. In addition to this, the shape and relative length of the rostral cartilage in relation to width or length of the cranium are more or less important for the taxonomy of this group.

(2). **Degree of forward extension of the pectoral fins**:- One of the great structural differences which exists between the two major forms of Japanese rajids is the degree of forward extention of the pectoral fins. Of this matter, however, a fairly good description was given dy BIGELOW and SCHROEDER (1948), followed by the present writer (1952), so that a brief note with biological significance shall be given in the present study.

In the southern form, the radial cartilages of the pectoral fins fall far from the tip of the snout, leaving a large semicartilaginous portion on both sides of the rostral appendices (Fig. 27). On the other hand, in the northern form the radial cartilages are very close near the rostral appendices without noticeable space (Fig. 28).

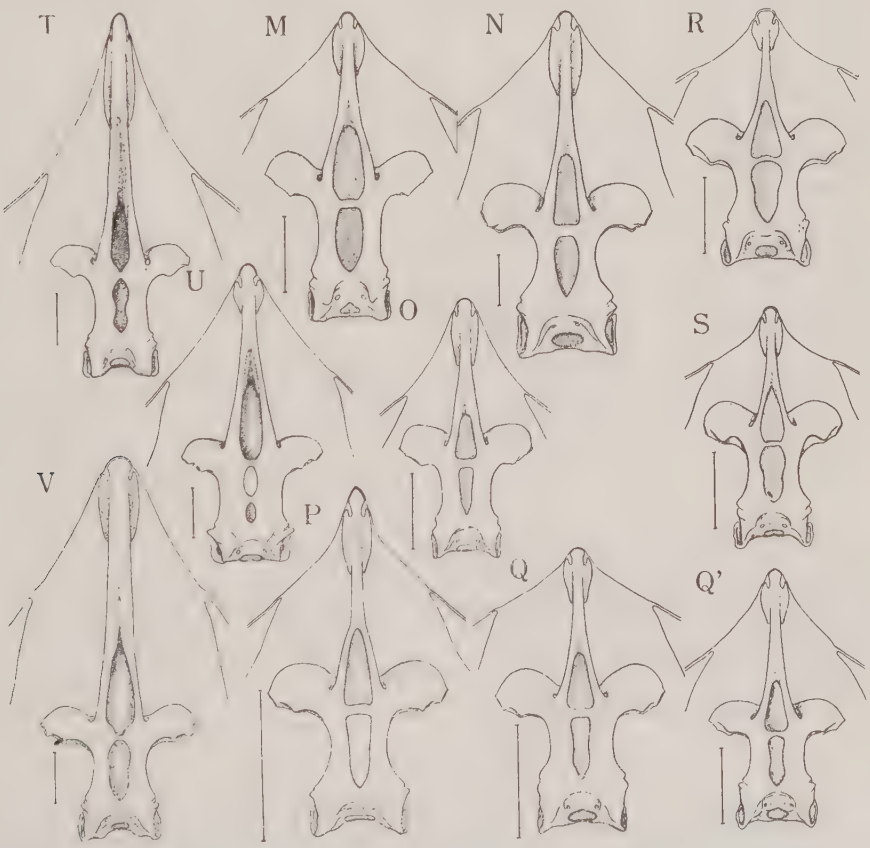

Fig. 27. Dorsal view of the cranium in the southern form, expecially showing differences in relative length of the rostral cartilage and the shape of the anterior and posterior fontanelle. M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q, *R. porosa meerdervoorti*; Q', *R. porosa tobae*; R, *R. fusca*; S, *R. schmidti*; T, *R. tengu*; U, *R. pulchra*; V, *R. macrocauda*. Scales represent 3 cm.

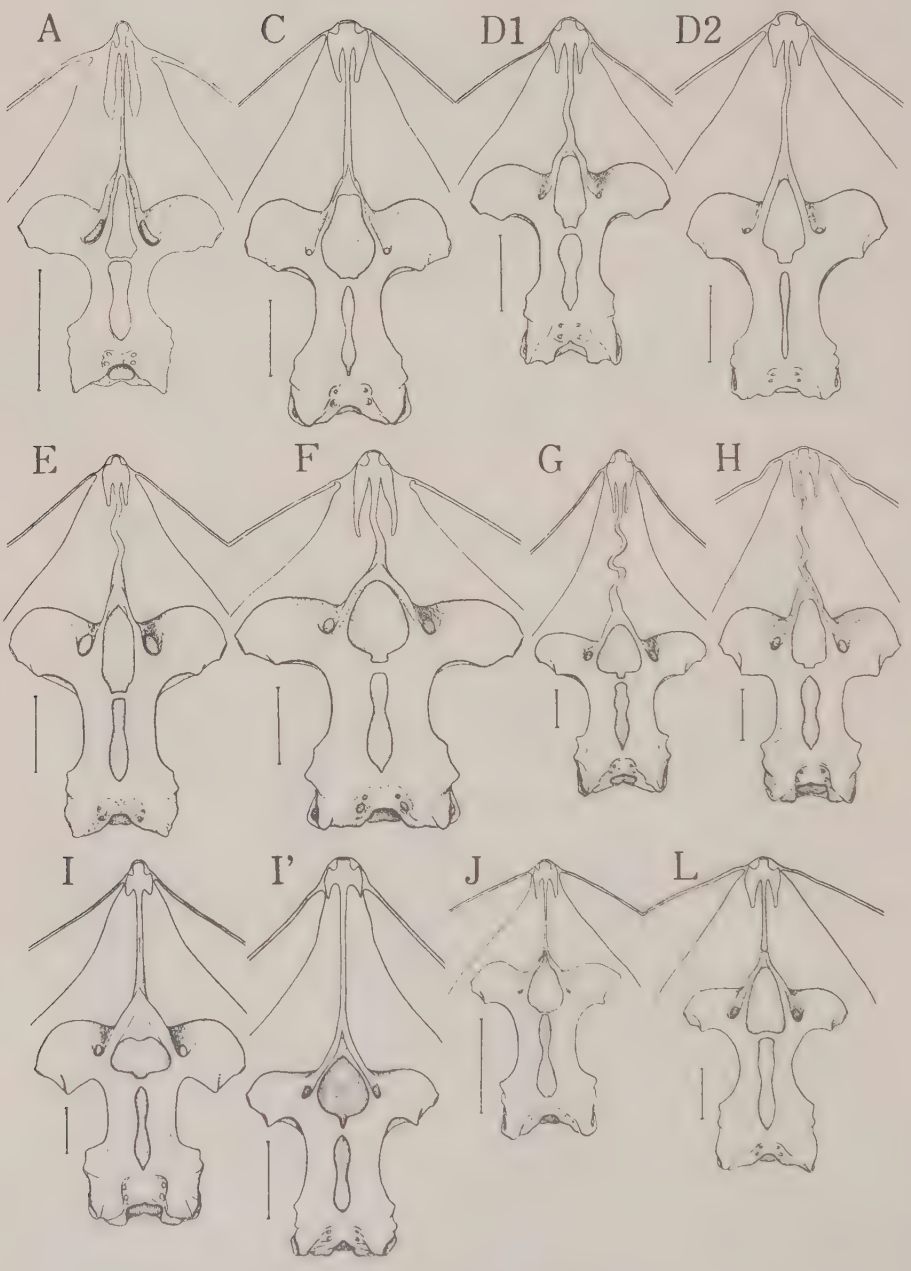

Fig. 28. Dorsal view of the cranium in the northern members, especially showing differences in the degree of development of the rostral appendix and presence or absence of the rostral segment developed at the basal portion of more or less elongated rostral cartilage, and in undulation of the cartilage and shape of the fontanelle, and also in remarkable forward extension of pectoral fines. A, *Breviraja tobitukai*; C, *B. trachouros*; D_1, D_2, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*, I', *B. smirnovi ankasube*; J, *Rhinoraja odai*; L, *Rh. longicauda*. Scales represent 3 cm.

Remarks:- A peculiar undulation of the rostral cartilage was observed in some species of the northern form when these preserved specimens or fresh ones were thoroughly dissected. This fact, however, is found to exist to some extent in all the members of this form, but it is characteristically revealed in species **G** (**G** in Fig. 28), whose rostral cartilage is very long and tapers. The phenomenon is thought to be unique in the northern members, especially so distinct in species referred to the genus *Breviraja*, and no such case could be seen in the southern members, (Fig. 27) as well as in a specimen involved in the northern form preserved in the formalin solution after the fresh specimen was dissected out (cf. Fig. 28 **C**, **I**, **I'**). Thus taking this fact into consideration, the phenomenon is forced upon the writer to take the following speculation as to this interesting feature in the rostral cartilage.

In most part of the pectoral fins of rajids, gentle undulatory vibrations of the margins may take place so as to give the fish the wave motions, by which pushing effort against water may be made. That is known as the pectoral type of locomotion (UCHIDA, 1930, pp. 9—10, Fig. 4). The wave motion, therefore, may be given in the greater part of the snout in the northern form so that the radial cartilages extend to distal part of the snout. On the contrary, the motion may be restricted only to the portion rearward the anterior tip of the radial cartilage that fall far from the distal tip of the snout in the southern one.

Then, it may be worthwhile to meet with a reasonable speculation as to the fact in question that synchronous vibratory function possible bending and rebending motions in the greater part of the snout of the northern form may have a possibility of shortening or lengthening to greater or less extent affecting combined effort from the two sides in the snout. If such a hypothesis be justifiable, the wave motion on both sides of the snout may dynamically oppose between the two major forms, and further, a segment developed on the basal part of the rostral cartilage of species belonging to the genus *Rhinoraja* may have been specialized from that of genus *Breviraja* so as to facilitate such mobility in the snout. If this view is really true, we may conceive that rather extensive individual variation in the length of the snout of the northern form may be caused by such elastic structure in the snout as mentioned above. And, it may also be considered that the strong undulation of the rostral cartilage is caused by elongated snout as is found in species **G** (**G** in Fig. 28).

b. Discussion

1. Analysis of genera and species of the Japanese rajids

The following key of genera and species of our rajids has been prepared in aid of clear separation of the fish by using such characters of the snout as: i) flexibility; ii) relative length measured in external; iii) features of the rostral cartilage and its appendices as well as their relative lengths; iv) degree of forward extention of the radial cartilages of the pectoral fins; and v) location and shape of both anterior and posterior fontanelle of the cranium.

1a. Snout usually blunt, but elongated and flexible in touch, and can easily be bent vertically in its most parts. Rostral cartilage very weak, slender rod or tape-like projection, reaching extremity of the snout, where the rostral appendix broadly developed with delicate cartilage on both sides (Type $S^{B,C}$); posterior ends of the appendix apparently free from the lateral sides of rostral bar. Anterior tips of radial cartilages of the pectoral fins very close to, or nearly contacted with, lateral edge of the appendix. Anterior fontanelle usually polygonal or curious in shape, excavating anteriorly covered with a cartilage without shallow depression.

2a. Rostral cartilage without segment ..... *Breviraja*

3a. Rostral cartilage about as long as or longer than skull; rostral appendix very long or moderately long, or even very small.

4a. Snout shorter than, or almost equal to, half the length of head. Rostral cartilage developed in slender, more or less undulated bar, almost as long as skull.

5a. Rostral cartilage much slender, bearing a pair of long, delicate rostral appendices or wings, which extend to half way to base of the rostral bar. Anterior fontanelle elongate into long furrow ..... *B. tobitukai* (Fig. 28 **A**)

5b. Rostral cartilage moderately thickened, bearing a pair of relatively small rostral wings, which are shorter than one-third of the length of rostral cartilage.

6a. Anterior tip of snout commonly blunt. Rostral cartilage developed in rod-like projection.

7a. Rostral appendix longer than one-fourth the length of rostral cartilage. Anterior fontanelle usually ellipsoid or pear-like in shape ..... *B. isotrachys* (Fig. 26 **B**); *B. trachouros* (Fig. 28 **C**); *B. abasiriensis* (Fig. 28 **D**)

7b. Rostral appendix shorter than one-fourth the length of rostral cartilage. Anterior fontanelle usually broad ..... *B. smirnovi smirnovi* (Fig. 28 **I**); *B. smirnovi ankasube* (Fig. 28 **I'**)

6b. Anterior tip of snout broadly blunt. Rostral cartilage rather flat ..... *B. parmifera* (Fig. 28 **H**)

4b. Snout always longer than half the length of head. Rostral cartilage developed in a long, tapered and exceedingly undulated bar, much longer than skull ..... *B. aleutica* (Fig. 28 **G**)

3b. Rostral cartilage much shorter than skull; rostral appendix long, longer than half the length of rostral cartilage ..... *B. matsubarai* (Fig. 28 **F**)

2b. Rostral cartilage with a segment at the basal portion ..... *Rhinoraja*

8a. Rostral cartilage rather thickened, bearing large rostral wings, which are half as long as rostral cartilage ..... *Rh. kujiensis* (Fig. 26 **K**)

8b. Rostral cartilage very slender, bearing small wings, which are shorter than half the length of rostral cartilage ..... *Rh. odai* (Fig. 28 **J**); *Rh. longicauda* (Fig. 28 **L**)

1b. Snout usually pointed anteriorly and apparently axiled in touch, and scarcely bent at the base. Rostral cartilage stout with heavy calcified rod, reaching extremity of the snout; distal portion of the cartilage bears a rostral appendix on both sides (Type S^A); posterior end of appendix fused to, or closely contacted with, the lateral side of the rostral cartilage. Anterior tips of radial cartilages of pectoral fins falling far from the tip of snout, leaving large semicartilaginous portion in front of the skull. Anterior fontanelle usually long, pointed anteriorly, elongated into shallow depression ..... *Raja*

9a. Snout much longer than half the length of head in stage above 100 mm of disc-width. Rostral cartilage stout and long, much longer than cranium.

10a. Rostral appendix in adult equal to, or longer than, one-third the length of cranium. Posterior fontanelle not divided into two holes.

11a. Rostral appendix in adult about half as long as rostral cartilage, the furrow of the latter elongated anteriorly, reaching beyond posterior end of the appendix ..... *R. tengu* (Fig. 27 **T**)

11b. Rostral appendix in adult shorter than half the length of rostral cartilage, the long furrow of the latter long, but not reaching posterior end of

the appendix ..... *R. macrocauda* (Fig. 27 V); *R. gigas* (Fig. 27 W)

10a. Rostral appendix in adult much shorter than one-third the length of cranium. Posterior fontanelle divided into two holes..... ..... *R. pulchra* (Fig. 27 U)

9b. Snout short or moderate in length, shorter than, or subequal to, half the length of head in stage above 100 mm of disc-width. Rostral cartilage somewhat longer, or shorter than the cranium.

12a. Rostral cartilage a little longer than or equal to length of cranium... ..... *R. kenojei* (Fig. 27 M); *R. acutispina* (Fig. 27 N); *R. hollandi* (Fig. 27 O); *R. macrophthalma* (Fig. 27 P); *R. porosa meerdervoorti* (Fig. 27 Q); *R. porosa tobae* (Fig. 27 Q′)

12b. Rostral cartilage shorter than the cranium..... ..... *R. fusca* (Fig. 27 R); *R. schmidti* (Fig. 27 S)

2. Consideration of the differentiation of the snout

One of the most important things in the systematics of rajids is found in both external and internal features of the snout. The evidences noticed by the present writer has led him to the following hypotheses in regard to the differentiation of the snout, which may have evolved in the two lines. i) specialization shown by gradual changes in the length of snout without noticeable structural differentiation, which may be revealed in the southern form; and ii) specialization shown by structural modification of the snout, which is revealed in the northern form. These hypotheses were developed based on the following facts.

1). **Length of the snout largely correlated with the depth of habitat**:- The depth of habitat observed in the species belonging to the genus *Raja* rangs from exceedingly shallow coastal waters down to about 200 fathoms. For example, the species which have a relatively shorter snout, such as species **R** and **S** (Fig. 25 **R**, **S**), usually inhabits the coastal waters, the adjacent regions at a depth of about 20 to 50 fathoms, or shallower waters. On the contrary, the species having longer snout such as **T**, **V** and **W** (Fig. 25) are generally found at a depth of about 100 fathoms or in the deeper regions. Further, the examples having moderate length of the snout such as **M**, **N**, **O**, **P**, etc. (Fig. 25) were fonnd to occur in the intermediate zone between the two extremes mentioned above.

Judging from these facts, the transformation in the relative length of snout of the southern form may presumably have occurred in close relation with depths of their habitats, though there may exist rather large geographical and also seasonal variations of the depths even in the same species. But it is interesting to note here that the similar tendency has been known to occur in the European rajids (Clark, 1922).

If the above supposition on the specialization of the snout in the southern form is justifiable, there are two possible lines in assuming the course of transformation in the organ, i.e. whether the snout with greater length is thought to be more primitive or advanced form. More exactly, whether the species **T** which has a longer snout is more primitive than the species **S** which has a shorter one, or the reverse is the case. In consideration of these two cases, the present writer has inferred the following two evidences:

(a). In comparison of the features of rostral cartilage between two rajids, **T** and **S**, and a guitarfish, *Rhinobatos schlegeli*, there are found some noteworthy facts, viz., the anterior fontanelle of the guitarfish is a long and deep furrow lying from

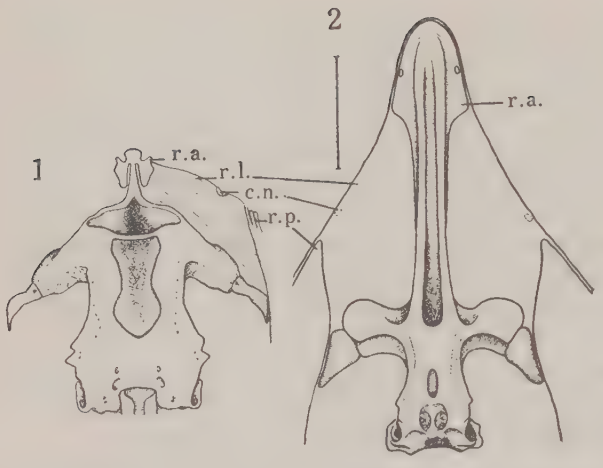

Fig. 29. Dorsal aspects of the crania of the two representatives; 1, *Raja clavata*, 90 mm in total length of a embryo, after HOLMGREN (1940, Fig. 147); 2, *Rhinobatatos schlegeli*, with scale of 3 cm. c. n., cartilage nodule; r.p., cartilages of pectoral fin; r. a., rostral appendix; r. l., rostral ligament.

the base to the distal tip of the long and stout rostral cartilage (2 in Fig. 29), which resembles more that of the species **T** than that of species **R** or **S** (Fig. 27). Further, the rostral appendix of the guitarfish is very broad and thin anteriorly, originating posteriorly near the midway point of the rostral cartilage, which seems to be a reminiscence of the appendix found in the species like **T**.

(b). It will be seen in Fig. 25 that in the southern form relative length of the snout is nearly the same in the young stages of various species whatever it shows remarkable difference in their adult stages (cf. Fig. 25).

The key to these two cases mentioned is a realization that the reduced snout of the adult is a neotenous condition*) of the elongated snout, i. e. the snout is masked in adult species **T** by subsequent lengthening, and is retained in adult **M** with moderate length, and is less produced in that of species **S** with much shorter snout, as has stated by DE BEER (1951) according to NICHOLS and BREDER (1928) for the evolution of flying fishes.

If this hypothesis is really true, the longer snout a species has, the more primitive condition it is in. In this case, therefore, species **S** may be in a more advanced condition than **T**, so far as their features of the snout in the southern form are concerned. It may be said that the snout may have been diversified into two directions in accordance with the depth of the habitat, viz., ones with relatively short snout are found in the fishes inhabiting either the deep seas or rather shallow waters, such as species **V**, **W** and **U**, and the other's which retain still shorter snout are represented by the fishes inhabiting the waters of shallower or coastal regions, as is observed in species **M**, **N**, **R** and **S** (cf. Table 1).

Thus, we can infer on the transformation of the snout in the southern form, basing the characteristics in both external and internal parts of the organ, that the differentiation of the snout may have taken place from the elongated snout to the shorter one, making an evolutional step upward with the changes of their habitats from moderate depth of the sea to either deep sea or shallow regions.

2). Structural modification revealed in relation to change of the utility of snout:- In the northern form, however, the rostrum has such complex structure that it is difficult for us to suppose their linealogical trends on the basis of the above mentioned hypothesis, but another hypothesis is needed for explanation. In this case, the flexible snout is surmised to have excellent advantage of seeking and blanketing food, such as

* Neoteny meaning the case where the adult retains larval character, or the case where the adult descendant resembles the young stage of the ancestor (DE BEER, 1951, p. 68).

fishes, crustaceans, etc. This specialization in the snout may have been caused by the forward expansion of the pectoral fins in the rostral region, undergoing retrogressive differentiation of the rostral cartilage. It is worth mentioning that a comparison of the rostral cartilage of Type S^B (Fig. 26 B) with that of a embryo of *Raja clavata* described by HOLMGREN (1941) shows us the homologous feature though these are referable to different genus. In other words, the feature of rostral cartilage of the species referred to the genus *Breviraja* may be in a neotenous condition in species of the genus *Raja*, the cartilage of which much resembles that of the guitarfish (2 in Fig. 29.) We may well believe that the rostral cartilage with Type S^B may be destined to the stoppage of succesive development of the old character which Type S^A accords, so as to make remarkable change in the rostrum with great influence of forward expansion of the pectoral fins. The present writer has developed the two following hypotheses partaining to the differentiation of the snout in the northern form:

(a). We may reasonably suggest that the species of poorly developed rostral cartilage with small appendix may be in a more advanced condition than that of rather strong cartilage with remarkable appendix. If this is really the case, species **H** and **I** (**I′**) may be regarded as more specialized than **A** and **F**, so far as the feature of rostral cartilage is concerned (cf. Fig. 28). The hypothesis seems also to hold true in the species referred to the genus Rhinoraja, i.e. species **J** of much more delicate rostral cartilage with less developed rostral appendix (**J** in Fig. 28) is thought to be in a more specialized condition than species K (K in Fig. 26).

(b). We may safely surmise that the anterior fontanelle is originally developed on the anterior portion of the chondrocranium, as seen in the guitarfish. But, as a rule, the shape and location are much varied in the Rajidae, especially in the northern members. As the similar features of the fontanelle occur rather consistently in closely related species and do not occur in widely separated ones, the features relating to the development of this organ may be used as linealogical consideration. Is it not possible to consider that the longer and the more anteriorly the fontanelle is, the more primitive condition it is? If this view is accepted, the fontanelle of the species **H** and **I** (**I′**) may reasonably be considered to be more specialized than those of **A** and **E** (cf. Fig. 28), although the condition of the organ is more or less variable not only in related species, but also in the sexes of a single species.

Granting the foregoing conception to be justifiable, however, it may be a far-fetched interpretation to suppose that further linealogical trends may exist in the snout of the northern form, especially in the genus *Breviraja* with much more diversification in the structure.

The degree of undulation, or serpentine feature of the rostral axis annotated elsewhere may be congruous with the mobility of the snout in some degrees, which seems to occur in parallel with the flatness of the cartilage. Such being the case, this character may be useful for a specific or superspecific demonstration in some species, but not for phyletic pedigree.

Summarizing the above, the characters thought to be important for phyletic evaluation in the snout of the Japanese rajids thus far examined are; i) relative length of the snout; ii) features of the rostral cartilage and its appendices; iii) presence or absence of the rostral segment; iv) degree of forward expansion of the radial cartilages of the pectoral fins; and v) shape and location of the anterior fontanelle. Of these features, ii), iii) and iv) may be valid for the generic relation, but i) seems important only for the subgeneric relation of the southern form, and v) may be very important for the consideration of interspecific relationships in the northern form.

Thus the characteristic features distinguished as specialization or degeneration are well seen in both external and internal parts of the snout. Such relations as specialization and reduction in characteristics of the snout and of the tail are apparently recognized as antagonical ones, as has been stated by the present writer (1952, '55). Namely, as in case of the southern form, when the specialization occurs only with modification by reduction of the snout from their ancestral form, the extreme specialization of the tail is recognized as will be explained later on (p. 66). On the contrary, the significant specialization in the snout which may be correlated with less specialization of the tail is revealed in the northern form. Further, such relations thus antagonizing each other between the specialization of the snout and of the tail may generally be confirmed in the sexes of the southern form, which provides sexual difference to some extent. To be more exactly, the relative length of the snout is usually greater in the female than in the male, while the tail is in most cases relatively shorter in the female than in the male (cf. Figs. 25, 31 and 32). Conclusively, the snout and the tail may have been evolved in counter relation each other in Japanese rajid fishes.

Finally, it should be noticed that the trend of the differentiation in the features of snout of Japanese rajids thus mentioned above seems to be in parallel with that supposed from the male organ, as a whole. But, the characteristic features even in both external and internal of the snout are not always evaluated as a specific constant of each species because the organ show much similar features in closely related forms, in some case.

b. Tail, its external features with special reference to the electric organ

1. Description and comparison of the tail and its electric organ

1). **External features of the tail:-** In taxonomy of batoid fishes, external features of the tail have generally been used for distinguishing each group of the fishes. In general feature, the tail of rajid fishes has been thought to be rather intermediate between those of the guitarfish and the sting ray.

In the present item, the shape, the length of tail relative to standard dimension (width of disc), the degree of development of the dermal folds on both sides, and the reduction of the distal portion are especially taken into consideration. In detail, the tail of rajid bears either depressed or rolled elongation in external appearance. Individual variations as well as sexual differences in relative length of the tail are more or less salient. The degree of development of the fleshy dermal folds on sides of the tail is closely related to that of the electric organ, except for one species (species **A**), but the reduction in length of the distal portion of the tail is of specially interesting phenomenon in the young stage throughout all the species dealt with here.

These external features should be considered to be in close connection with internal ones, but here, as for the sake of convenience for description, some points of greater importance in externals have been alluded to as well.

(1). **Outline of the tail:-** Though it may be stated that the tail of the rajid seems originally to be for locomotion, the organ remains at a stage of development insufficient for propelling the body, and is in the state of reduction to some extent. When the tail is cut off at the insertion of the first dorsal fin, the outline in cross view shows two rather defined features, and is called herein respectively round- and depressed-type.

Round-type (**A** in Fig. 30): In this probably primitive form, the tail is largely cylindrical and rod-like in shape, with round upper border and flattened under surface. Fishes with this form of the tail accompanied by general elongation are characteristi-

cally referred to the northern members with exceptions of three examples, such as H, I and I′ (Fig. 35 H, I).

Depressed-type (U in Fig. 30): Still more advanced form is found in the depressed-type of the tail, in which the tail is much lower than wide, in most cases. Fishes with this form of the tail remarkably reduced in length are represented by the southern form and three examples of the northern one aforementioned, and this makes us infer

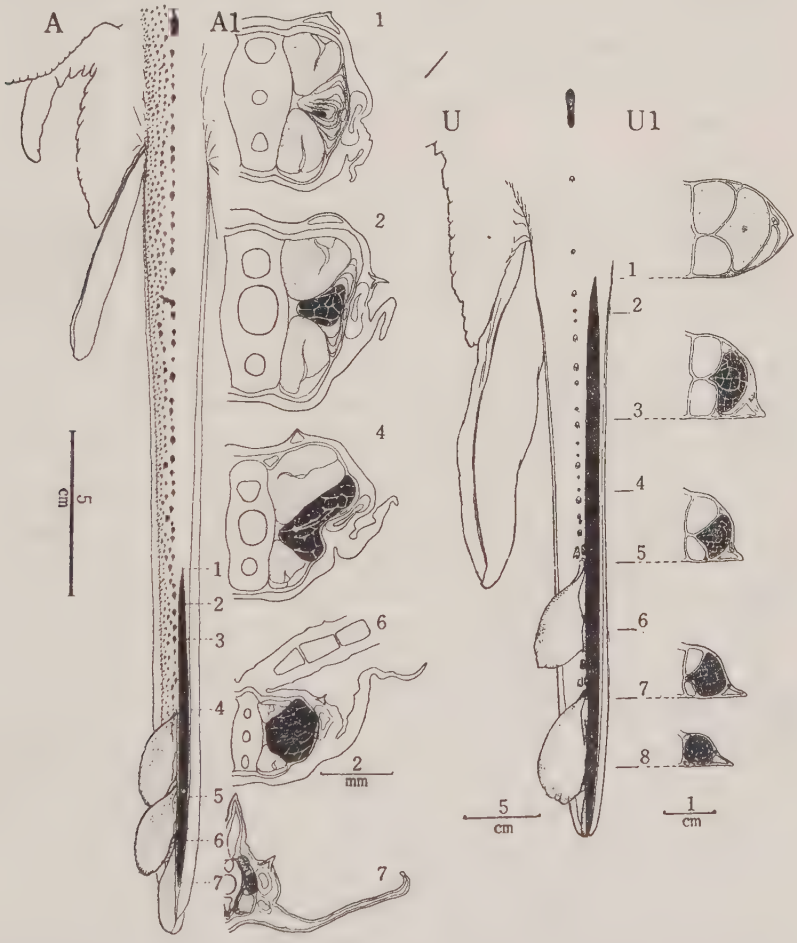

Fig. 30. Showing the two representatives in the outline of tail and in the manner of location of the electric organ exposed by dissection, or shown by cross section at several portions where the organ lies. Black spindle in A (*Breviraja tobitukai*) and U (*Raja pulchra*) represents dorsal aspect of the electric organ when exposed from the surrounding tissue; cross view in the two forms is arranged in the two series (A_1 and U_1), ranging vertically 1, 2 ..... 7 or 8, which correspond to those numbers assigned in A and U.

that the form of the tail may be more conventional for the bottom living than that of the preceding.

At any rate, though there appears to be two types of the tail mentioned above in its external view, the anterior portion in both types of the tail is similarly thickened as is the case with that of the shark. From this fact it may be said that the diverge

in the form of the tail has occurred from anterior portion to rearward.

Tails can be divided in two types, so far as external features are concerned, but this distinction is a conventional way of dividing tails at a glance, because between the two extremes there are some forms intervening, making it almost impossible for us in strict sense to draw a border line between the two types mentioned above.

(2). **Length of the tail:-** In the RAJIDAE, as in some other features, the length of the tail is defined in two diversed groups. In one group the tail is long irrespective

Table 7. Ratio of proportional measurement of tail measured in disc-width in three stages of Japanese rajids. For abbreviations, see text.

Stage and ratio	Juvenile		Adolescent				Adult			
			male		female		male		female	
Species	range	average	range	average	range	average	range	average	range	average
A	—	—	0.48—0.89	0.87	0.48—0.90	0.87	0.87—0.92	0.89	0.81—0.89	0.84
B	0.99—1.18	1.09	1.17—1.25	1.20	1.11—1.23	1.17	1.23—1.28	1.25	1.22—1.25	1.23
C	0.94—1.24	1.04	1.08—1.18	1.12	1.05—1.09	1.07	1.15—1.25	1.21	1.13—1.38	1.21
D	—	—	—	—	—	—	1.12—1.61	1.28	1.16—1.32	1.24
E	1.04—1.17	1.10	1.12—1.26	1.18	1.13—1.28	1.19	1.21—1.28	1.24	1.18—1.33	1.25
F	0.91—1.13	0.98	1.04—1.16	1.08	1.07—1.08	1.07	1.09—1.16	1.14	1.10—1.12	1.11
G	1.07—1.13	1.09	1.04—1.22	1.13	1.05—1.18	1.11	1.19—1.29	1.23	1.20—1.37	1.26
H	—	—	—	—	—	—	1.41	—	—	—
I	1.50—1.69	1.53	—	—	1.63—1.67	1.65	1.50—1.75	1.56	1.47—1.69	1.59
I′	1.37—1.73	1.50	1.56—1.75	1.63	1.55—1.66	1.62	1.66—1.78	1.72	1.66—1.75	1.72
J	—	—	0.95—1.05	0.99	0.92—0.99	0.95	0.99—1.07	1.01	0.99—1.06	1.02
K	0.86—0.98	0.91	0.88—1.11	1.01	0.95—1.28	1.03	1.12—1.20	1.16	1.05—1.26	1.18
L	0.87	—	0.94—1.12	0.99	0.88—0.96	0.92	0.96—1.08	1.01	0.92—1.01	0.96
M	1.05—1.48	1.37	1.33—1.48	1.39	1.37—1.58	1.46	1.26—1.42	1.34	1.36—1.50	1.41
N	1.24—1.37	1.32	1.34—1.54	1.44	1.27—1.50	1.39	1.36—1.43	1.39	1.42—1.62	1.50
O	1.26—1.34	1.29	1.23—1.40	1.31	1.27—1.40	1.35	1.16—1.36	1.25	1.35—1.52	1.44
P	1.18—1.44	1.32	1.26—1.42	1.33	1.24—1.68	1.47	1.18—1.28	1.23	1.23—1.48	1.34
Q	1.23—1.46	1.36	1.32—1.52	1.42	1.35—1.56	1.41	1.16—1.48	1.32	1.33—1.50	1.44
Q′	1.12—1.38	1.26	1.29	—	1.33—1.42	1.36	1.20—1.38	1.26	1.31—1.48	1.40
R	1.30—1.49	1.40	1.43—1.58	1.49	1.34—1.55	1.43	1.34—1.52	1.42	1.40—1.54	1.49
S	—	—	1.23—1.46	1.33	1.32—1.46	1.37	1.18—1.29	1.23	1.30—1.50	1.37
T	1.19—1.39	1.30	1.41—1.75	1.58	1.39—1.78	1.56	1.65	—	1.67—2.04	1.84
U	1.05—1.73	1.19	1.32—1.76	1.56	1.24—1.78	1.57	1.41—1.69	1.57	1.70—1.73	1.71
V	1.00—1.43	1.15	1.31—1.59	1.49	1.23—1.60	1.40	1.55—1.70	1.61	1.67—1.82	1.74
W	1.27—1.48	1.34	—	—	1.53—1.62	1.56	1.55—1.57	1.56	1.57—1.67	1.62

of sex, which is characteristic of the northern form, whose proportional ratio of the tail in the adult against the width of disc is from 0.8 up to 1.2, with some exception, such as three examples H, I and I′, where the ratios are from about 1.5 up to 1.7. In the other group is reduced in length, which is characteristic of the southern form, its ratio being from about 1.0 up to 2.0. Furthermore, in the southern form, the tail undergoes sexual difference to some extent in its length, being usually longer in male than in female if compared with the same-sized fish of the species. Although the relative length of tail in the rajids may be attributed to a high degree to classification

of this group, it varies to some extent with sexes and even with growth of the fish (Table 7).

(3). **Relative length of the tail in sequence of growth of the fish:-** The relative length of tail varies rather extensively with the growth of the fish throughout the species here dealt with through a considerable number of specimens. A comparison of the variation indicated by the ratios against the width of the disc shows three types in their trends, viz., Types T-1, T-2 and T-3. The proportional ratio rather simply increases without any sexual differences with the growth of the body in Type T-1,

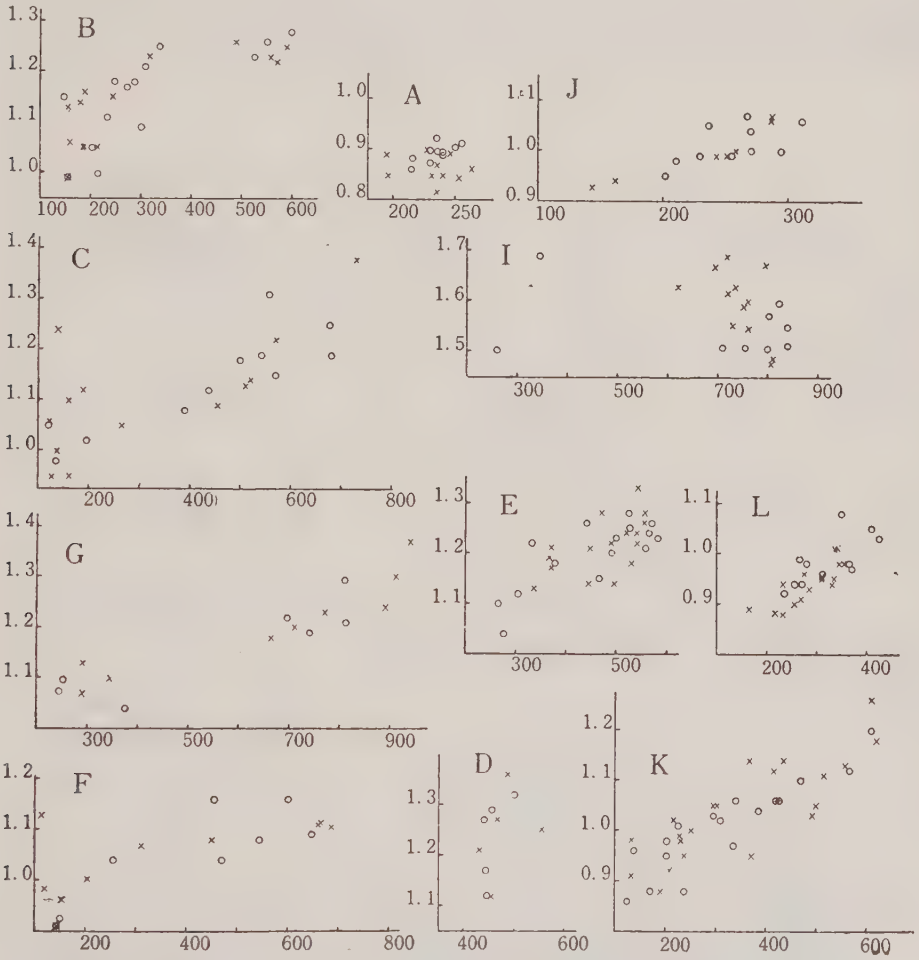

Fig. 31. Ratio of tail in length against width of disc in relation to the width (mm) in the northern form; ordinate, ratio; abscissa, disc-width; circle, male; cross, female. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*, I, *B. smirnovi smirnovi*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*.

in which all of the species belonging to the northern form may be comprised (Fig. 31). The ratio first suddenly increases, either constantly or slightly, and then, remarkable sexual difference occur in most cases of Type T-2, in which almost all of the species referred to the southern form may be included with the exception of the species R. (Fig. 32).

The curve gradually changes, at first, increasing its ratio, then followed by an easy grade in Type T-3, to which four species of the southern form belong. (T, U, V and W in Fig. 32).

Thus, the mode of the change of the proportional ratio of the tail may be classed into three types, which may be regarded as intricate problems. The tail of the rajid, however, may not grow evenly throughout the entire portion but differential growth occurs locally, and is eventually destined to diminish in its distal part as described later on. In either event, it may generally be pointed out from these figures that the mode of transformation in the relative length of the tail portion, if compared biometrically, may be classed into three types as mentioned above with some exceptions (Table 7).

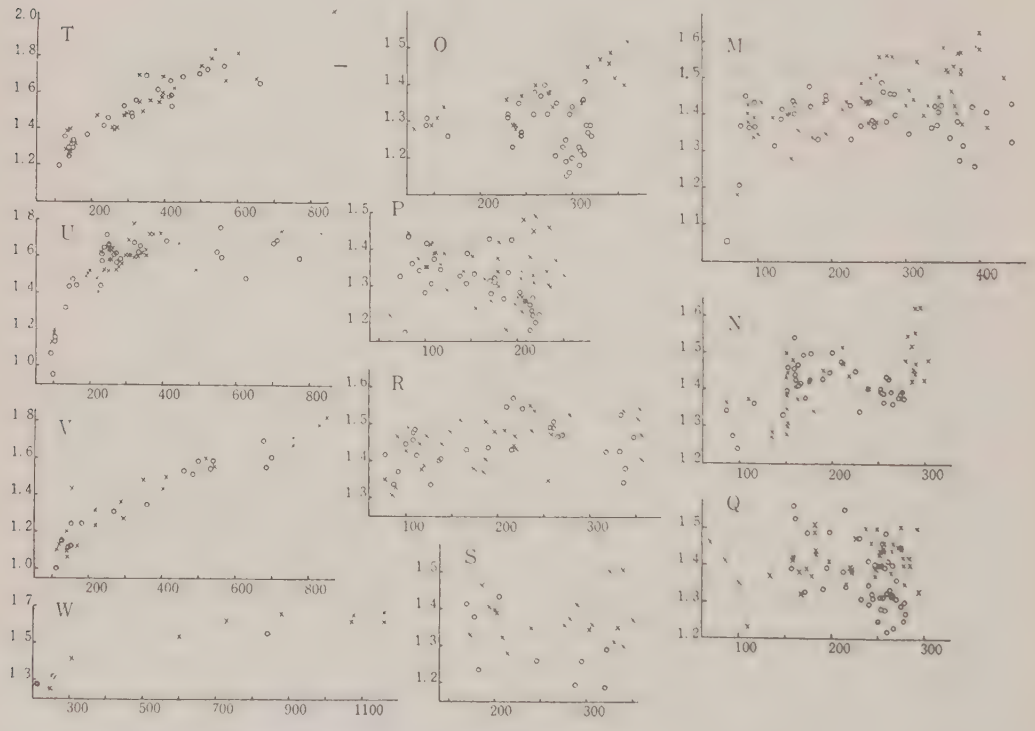

Fig. 32. Ratio of tail in length against width of disc in relation to the width (mm) in the southern form; ordinate, ratio; abscissa, disc-width; circle, male; cross, female. M, *Raja kenojei*; N, *R. acutispina*, O, *R. hollandi*, P, *R. macrophthalma*, Q, *R. porosa meerdervoorti*; R, *R. fusca*; S, *R. schmidti*; T, *R. tengu*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*.

(4). Metamorphosis of the tail in later embryos of some species:- Four stages of the embryo of *Rhinoraja kujiensis**) were illustrated to show especially the change in the proportion of tail and its external feature. In addition to the above

* These specimens were secured by a motor-trawler of the Hachinohe Branch Station of Tohoku Regional Fisheries Research Laboratory during the survey of the deep seas off the Pacific coast, and were kindly placed at the writer's disposal.

mentioned materials, several specimens of the post-embryos and the young of *R. kenojei* and of other species taken by the writer have also been treated here. All of these embryos were extruded from those egg-capsules. In order to compare briefly these specimens under the present scheme, it may be convenient to give an account of the principal features at each stage of the embryo of *Rhinoraja kujiensis*, which are to be mentioned in the first place.

Rhinoraja kujiensis:- Body is very slender, bearing an enormously large yolk-sac; head is greatly delated eminence, bulking over the snout region; the eyes are well formed; the external gills are apparent, protruded from incomplete gill-slits; the spiracles are developing into conspicuous clefts immediately before the gill-slits. Both pectoral and pelvic fins are distinct but small, being in outward expansion on lateral

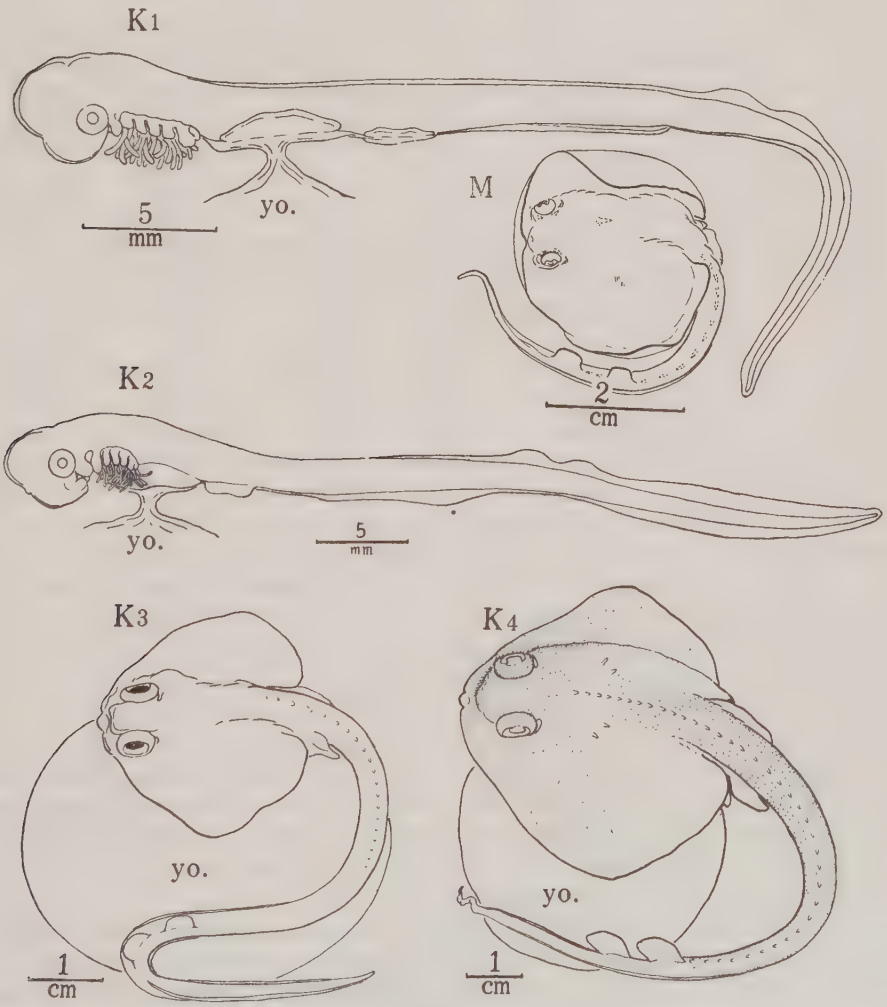

Fig. 33. Later embryos in the two species, K_1—K_4, *Rhinoraja kujiensis*, and M, *Raja kenojei*, especially showing long caudal portion, which is complete in K_1—K_3 and M, but it is in process of shrinkage in K_4. yo., yolk-sac.

sides; dorsals are well-established, inserted ensuring far back between head and rear end of the tail. The tail behind dorsals is long, measuring about one-fourth times as long as total length of the boby. This specimen may be corresponding approximately to BALFOUR's stage N in the shark, (Fig. 33 K_1).

The embryo (Fig. 33 K_2) has essentially the same feature as that of preceding one, but it calls our attention particulary to the following: The pectorals and pelvics are even precociously larger; the two dorsals are rather distinct, located anteriorly on the notably long tail; the tail portion measured from posterior end of the 2nd dorsal to rear end is about one-third times as long as the total length. It may be meaningful to find a elevation of the fin-fold lying far behind the pelvic fins. This may be a vestige of the anal fin, which is called herein tentatively anal fold.

The further advanced embryo shows a form decidedly like a skate, as can be seen from the figure; it has well-established pectoral fins, their anterior tips being closed together, interposing a short projection of the snout between them; the dorsals are located far back on the tail as in the case of the foregoing specimen; the pelvics are already notched. The characteristic features of this embryo are that the long caudal tip behind the second dorsal is complete without a sign of reduction, and the caudal and the membraneous folds on lateral sides of the tail are still distinct. The anal fold in question is also evident. The embryo is yet attached to a large mass of the yolk-sac. A series of tubercles or rudiments of the thorns is running from opposite side of the cloaca to posterior, but the tubercles are becoming smaller toward midway of the tail. The eyes are pigmented, and the disc is margined with faint gray. The embryo may be corresponding approximately to BALFOUR's stage P in the skate (Fig. 33 K_3).

The embryo (Fig. 33 K_4) has a very similar appearance to the specific features of the species; the spination characteristic of the species has well developed as large spines on the mid lines of the disc and of the tail and on the shoulder, by means of which we can most readily distinguish this species from other relatives. Upper surface of the body is gray in color instead of being white on under surface. The most attractive feature in this embryo is that a long distal portion of the caudal fin still remains behind the second dorsal, being in process of reduction, and its extreme tip has begun to show signs of shrinkage, undulating irregularly. Further, it may be of note that the said anal fold still remains as a very thin membraneous fold occurring midway between the cloaca and insertion of the first dorsal fin. As the embryo approaches a stage of emergence from the egg-capsule, the reduction of the tail behind the base of second dorsal becomes remarkable, and the phenomenon occurs only in the embryonic tail end, where the horizontal dermal folds on the lateral sides of the tail are not developed. At the stage where the caudal region has assumed to have similar appearance to that of the adult, the young attains to about 230 mm in total length.

As described above, the metamorphosis in the caudal portion of *Rhinoraja kujiensis* occurs gradually at about the end of the post-embryonic stage, and is found sometimes to continue to the stage after the embryo has hatched out.

Breviraja isotrachys:- Several specimens of the young of this species, measuring from 222 mm to 253 mm in total length, which were also trawled in the seas off the northern Hondo, have showed to occur the metamorphosis of the caudal portion in question in the same manner as in the preceding species. Namely, the tail of young fish measured 253 mm still keeps its caudal portion long, being curl and shriveling in the tip (Fig. 34 **B**). At the stage when the fish attains 300 mm in total length, however, the caudal tip in question almost assumes adult form in its general appear-

ance (cf. Fig. 62 B_3).

Raja kenojei:- The latest embryo illustrated together with its young specimen of this well-known species may well exhibit the metamorphosis in the caudal tip. In Fig. 33 M, the tail region is still long, somewhat slenderer toward its rear end, and measures at the 2nd dorsal rearward about one-third times as long as the tail-length, and besides, the yolk-mass remains, though reduced in size, with a fully-developed external form approaching the adult of this species. In the youngest specimen measuring 100 mm in total length, which must have been lately hatched out from the egg-case, the metamorphosis of the tail is much progressed as compared with the foregoing one. It is a noteworthy fact in this case that the proccess of metamorphosis in the caudal region may have acceleratively taken place after the

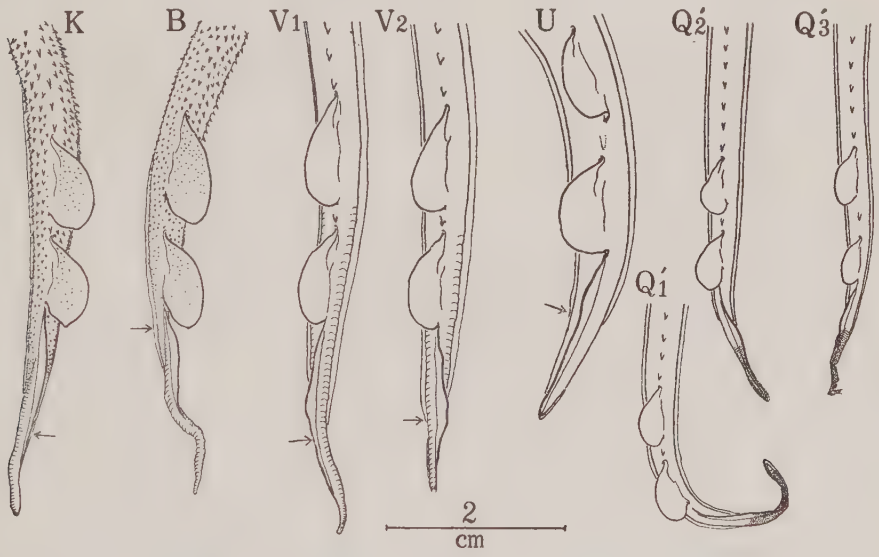

Fig. 34. Dorsal aspect of distal part of the tail in the young and the late embryos of five species, especially showing long caudal portion behind 2nd dorsal fin, where the portion is in process of shriveling or dropping out. Accompanying arrows indicate the portions where the electric organ was found to extend from anterior portion (cf. Fig. 46). B, *Breviraja isotrachys;* K, *Rhinoraja kujiensis;* Q'_1—Q'_3, *Raja porosa tobae;* U, *R. pulchra;* V_1—V_2, *R. macrocauda.*

embryo has emerged from the egg-case with rapid shrinkage and dropping-out of the distal part of the tail.

Raja pulchra:- Of the embryo of this species only the latest one known to the writer is available for the present study, and this still has a small, spherical yolk-sac, which shows us that it is just before the times of its hatching-out from the egg-case. Noteworthy in this specimen is the fact that the said caudal portion still remains, and is plump in its general appearance. It must also be mentioned that the long caudal portion shows the obvious metameric segmentation and the horizontal dermal folds on both sides do not extend to the posterior extremity of the tail (U in Fig. 34). This condition is peculiar in contrast to that of the younger specimen of *R. macrocauda* which inhabits the deep seas. The caudal tip of the species still remains, the portion is about one-half time as long as that of the adult (Fig. 34 V_1, V_2).

From the foregoing observation on various stages in the late embryonic development of a number of rajid fishes, it may be summarized that; i) remarkable metamorphosis occurs in the distal part of the tail; ii) the metamorphosis in the tail takes place by means of shrinkage and dropping-out only in the portion behind the dermal folds not at all developed on both sides of the tail; iii) the duration for the metamorphosis seems to differ between the northern and the southern form, i.e. the embryonic tail in the northern form remains longer after the young has emerged from the egg-case than seen in the southern one, and iv) the deep-sea inhabitants even in the southern members appear to need longer time for the metamorphosis of the tail than the shallow inhabitants.

2). **Internal features of the tail with special reference to the electric organ:-** The existence of the electric organ in the rajid fishes has hitherto been little noticed from systematic viewpoints of ichthyologists, though we have a good many contributions concerning both anatomical, physiological and biochemical studies on this strange organ. As already known, the electric organ in rays and skates is found in the two families of the batoids, placed in the disc of the torpedo and in the tail of the skate. The organ of the torpedo is generally thought to be more advanced in its structure than that of the skate, and the skate's organ is practically recognized to represent some primitive features somewhat similar to histological features of the fish muscle*). In the present account, the writer has limited only to gross anatomy of the organ with a view to arriving at some conclusion under the subject.

(1). **On some aspects of the electric organs of rajid fishes:-** As I have already described previously in other reports (ISHIYAMA, 1955), the electric organs of Japanese rajids are found to be classified in two distinct forms from electrical elements constituting this organ, the cup- and disc-form, respectively, which have long been known to exist in European skates. Of these forms of the organ, the former type is found to mark the organ of the northern form, and the latter characterizes that of the southern one. The difference in minute structure between these two types of the element is remarkable as is the case with the European skates which have been well mentioned by several authorities, especially by EWALT (1888, '92) and ROBIN (1865).

(i). General feature of the electric organ:- The electric organ of the skate may largely be observed as spindle-shape in outward appearance when it is exposed from under the muscle and dermal tissues on both sides of the tail (Fig. 30). On the other hand, difference in horizontal location of the organ in the tail between the two forms is remarkable. In the northern form, the organ is found to exist only in the posterior portion of the tail, falling far from the cloaca or from the emergence of pelvic fins (**A** in Fig. 30). In this case, moreover, it should be borne in mind that the organ gradually migrates forward as the greater it becomes, the less the portion where the organ lies in the procaudal portion, and, on the whole, the shorter the tail (Fig. 35).

In the southern form, however, the organ usually lies in the place from near the base of tail to its distal end (**U** in Fig. 30). The transpecific forward migration of the organ as notified above is also found to exist in this form, viz., the increase of relative size of the organ accompanies not only some changes of outward growth of the organ and gradual increase of the organ located in the precaudal portion, but also gradual decrease of the organ in the procaudal one as can be best understood from those contradistinguishing figures (Figs. 35, 36 and 37).

The relation of the electric organ to its surrounding parts of the body is clearly

* For minute structure of the skate's organ, see ISHIYAMA and KUWABARA, 1955 and '56.

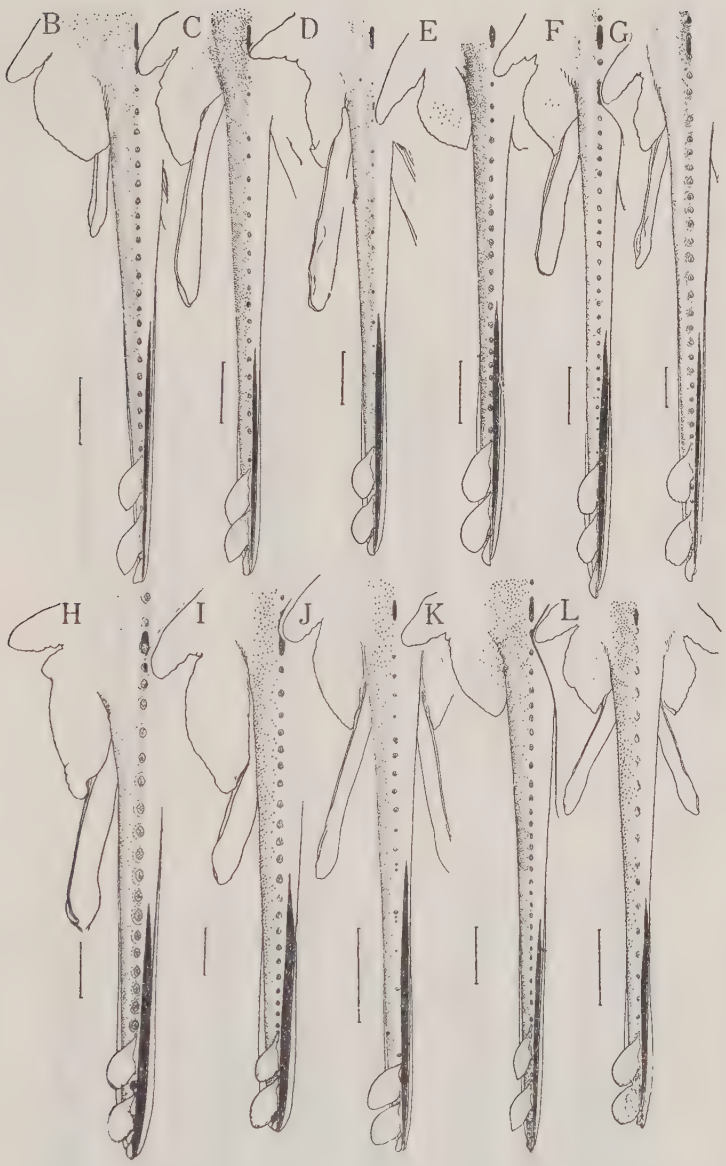

Fig. 35. Semidiagrammatic illustration of the dorsal view of the tail in eleven northern species, especially showing both the electric organ and the spination. The electric organ is shown by black on right side of the tail; the spination is shown only on the left side; the black slit in the anterior end in each figure represents the cloaca on opposite side; all these figures accompanying scales of 5 cm were arranged in equal size by way of comparison, and so forth in the following figures. B, *Breviraja isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi smirnovi;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda.*

observed in outline when a transvers section of the tail is made where the organ lies, and is seen under the microscope with a low power (A_1 and U_1 in Fig. 30).

(ii). The number and the mode of distribution of electric elements in the elctric organ:- It is practically difficult to compare the degree of development of the electric organ in each species of rajid fishes because the transpecific differentiation of the organ accompanies not only changes in size, but also differences in structure. But the

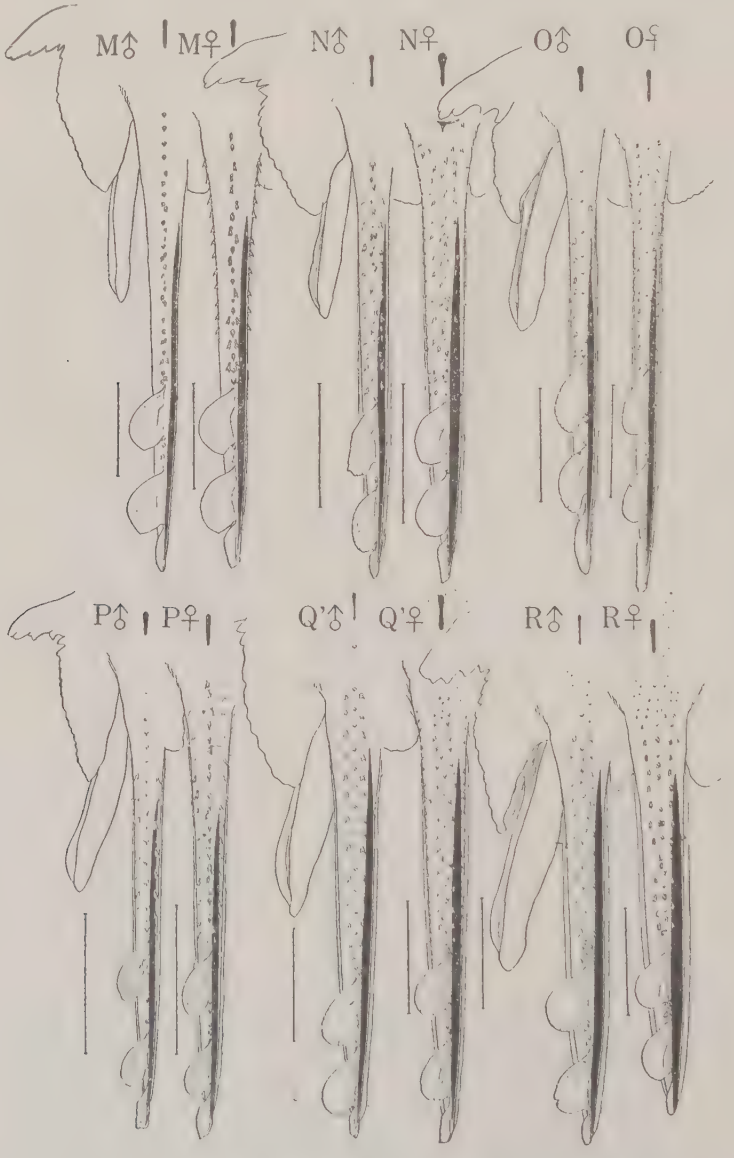

Fig. 36. Semidiagrammatic illustration of the dorsal view of the tail in six southern species, especially showing the distributions of both the electric organ and the spination. The method of illustration is the same as in Fig. 35. M♂, M♀, *Raja kenojei;* N♂, N♀, *R. acutispina;* O♂, O♀, *R. hollandi;* P♂, P♀, *R. macrophthalma;* Q'♂, Q'♀, *R. porosa tobae;* R♂, R♀, *R. fusca.*

present writer has estimated, for brevity's sake, the number of elements existing in an organ of each species by means of cutting sections of the organ (ISHIYAMA, 1955).

Concerning the number of the elements in an organ of the skate several accounts have been given. In *Raja batis*, about 10,000 discs on each side of the organ were estimated by EWALT (l. c.). The method of estimation taken in this study may be

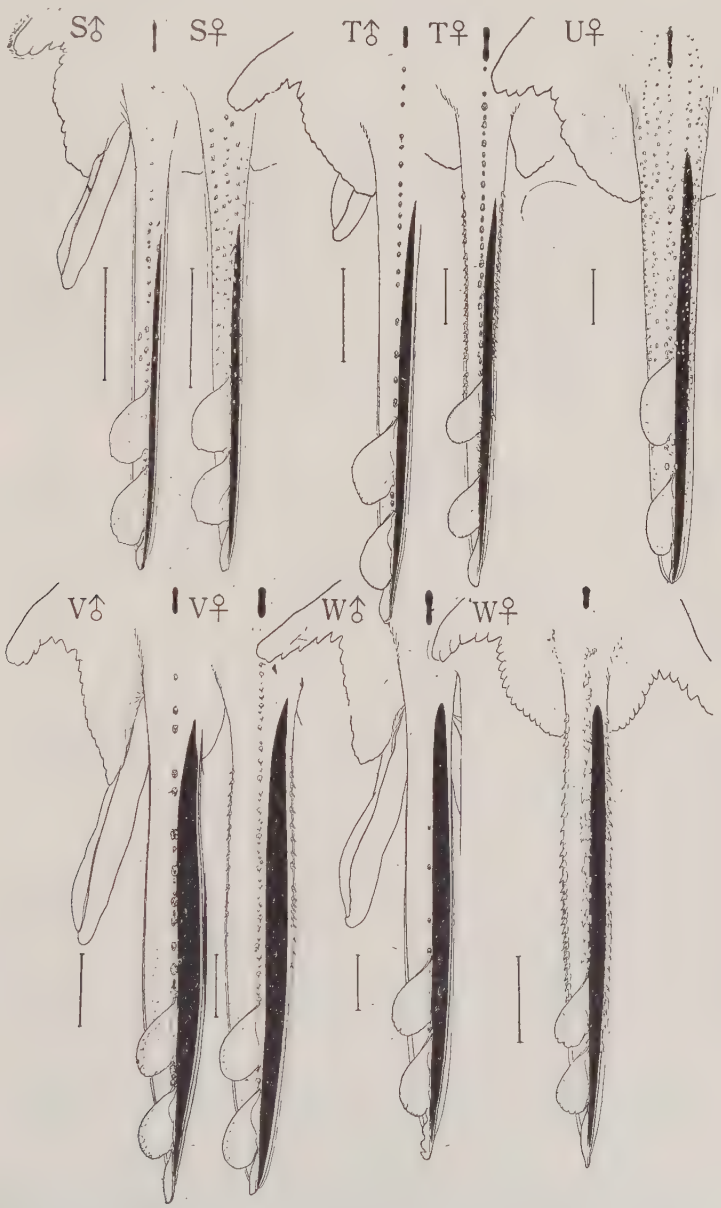

Fig. 37. Semidiagrammatic illustration of the dorsal view of the tail in five southern species, showing the distribution of both the electric organ and the spination. The method of illustration is the same as in Fig. 35. S♂, S♀, *Raja schmidti;* T♂, T♀, *R. tengu;* U♀, *R. pulchra;* V♂, V♀, *R. macrocauda;* W♂, W♀, *R. gigas.*

rather rough, but it would be of some use in appreciating the comparison of degree of development of the electric organ between species or group of species in combination with other characteristics of the organ.

As a step to the method of estimation given by the writer as aforementioned, the number of elements in an organ should be noticed: i) the elements are more numerous in larger species than in smaller one belonging to either the northern or southern form, in most cases, i.e. the least number was in the species **A** and **P** of each form, amounting to about 3400 and 4800, respectively, both species (**A** and **P**) represent the smallest in size in the each group. The maximum number, on the other hand, was found in large species, such as species **I** and **V**, in which the number is 27000 and 80000, respectively, ii) the numerical ratio of the elements between the two portions of tail divided represents close relation to the degree of development of the organ in the external feature. Namely, the procaudal elements are apparently more numerous than the precaudal ones in species **A**, **P** and **O**, whereas the reverse is the case in species **I**, **V** and **W**, and almost the same number of procaudal and precaudal elements is found in species **B**, **C** and **F**, but in the other species the precaudal elements are larger in number than the procaudal ones, and iii) in the southern form, the numerical ratio between the precaudal and the procaudal elements is different in more or less extent between two sexes; usually the procaudal elements relative to the

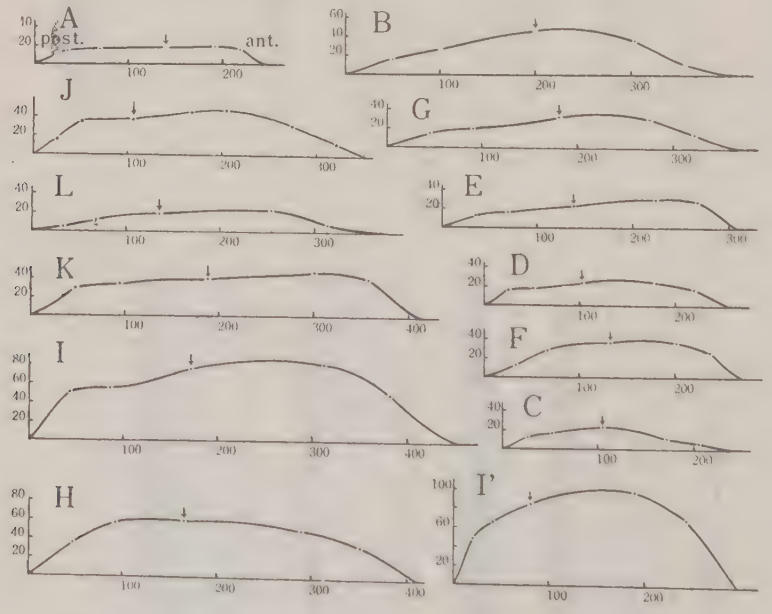

Fig. 38. Curves showing the distribution of electric elements in an organ of twelve forms of the northern members. Number of the elements given by cross sections at five or seven positions of the organ was plotted on vertical axis, and that in longitudinal sections at the same positions of the organ was given on horizontal axis. The arrow indicates the origin of 1st dorsal fin. ant. and post. being anterior and posterior extremity of the organ. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi*; I', *B. smirnovi ankasube*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*.

precaudal ones are more numerous in female than in male, though there exist some exceptions to these facts (Table 8).

As regards the mode of distribution of the elements in the organ by far estimated the writer has noticed that, i) the curve representing the mode of distribution of the elements in an organ is smooth in its main portion without any remarkable elevation in species **A** and **L** of the northern form, and in species **O**, **P** and **U** of the southern one, which have relatively smaller electric organs in their relatives; ii) the height of curve increases firstly in the precaudal portion as in the case of the species **B**, **D**, **E** and **G** in the northern members, and **N**, **Q** and **T** in the southern ones, in which the organs are moderate in the degree of development; iii) the height of curve becomes higher throughout the organ in species, of which the organ is remarkably large, as represented by **H**, **I** (**I'**), **V** and **W** within respective form (Figs. 38—40); and iv) the transpecific changes in the mode of distribution mentioned correspond largely to retrogressive reduction in number of the elements involved in the procaudal,

Table 8. Number of electric elements in precaudal and procaudal portions of the tail and the dimension in three bodily parts in Japanese rajids. In the northern form (A—L), samples were used either the male or the female of adult fish of each species, but in the southern form (M—W), both of male and female of each species were treated.

Item / Species and sex	Total length (mm)	Disc-width (mm)	Tail-length (mm)	No. electric elements: precaudal ♂	precaudal ♀	procaudal ♂	procaudal ♀
A, ♀	496	248	300	—	1383	—	2096
B, ♂	794	520	423	6080	—	5298	—
C, ♂	832	542	456	1869	—	1680	—
D, ♂	703	446	396	3325	—	2067	—
E, ♀	797	556	430	—	4326	—	2265
F, ♂	946	600	515	4280	—	3217	—
G, ♂	1280	811	672	4648	—	3527	—
H, ♂	941	645	455	11321	—	7357	—
I, ♂	1105	800	530	17825	—	9265	—
I', ♀	868	665	379	—	17555	—	4473
J, ♂	520	311	293	8380	—	2891	—
K, ♂	680	420	395	7905	—	5656	—
L, ♂	606	365	370	3743	—	1521	—
M, ♂ ; ♀	585 ; 543	409 ; 400	290 ; 248	5519	6068	4316	3830
N, ♂ : ♀	399 ; 405	266 ; 278	195 ; 200	4685	4322	2754	3495
O, ♂ ; ♀	493 ; 486	321 ; 340	245 ; 243	5151	7473	12879	9222
P, ♂ ; ♀	350 ; 345	224 ; 232	183 ; 173	2615	2270	3426	3070
Q', ♂ ; ♀	480 ; 485	320 ; 320	245 ; 241	7428	3932	2426	2442
R, ♂ ; ♀	487 ; 325	339 ; 236	245 ; 252	8672	6175	5760	2620
S, ♂ ; ♀	465 ; 446	288 ; 303	241 ; 225	3268	2983	3225	3429
T, ♂ ; ♀	728 ; 1130	562 ; 850	322 ; 470	17340	11532	10620	19404
U, ♂ ; ♀	965 ; 1119	710 ; 830	420 ; 491	8107	5232	5008	6624
V, ♂ ; ♀	1000 ; 1250	700 ; 800	435 ; 465	37440	52416	15744	28448
W, ♂ ; ♀	1210 ; 1540	840 ; 1160	540 ; 693	45326	45216	21324	32030

and progressive development in that found in the precaudal.

(2). Later embryonic development of the electric organ in some rajids:- The early development of the electric organs of certain skates has been sufficiently studied by EWALT (l. c.). Therefore, there is a little escape in question in our rajids from those valuable accounts made by the past savant on the subject.

Under the present item a histological study has been made with the study of probable relation between degree of development of the electric organ and the metamorphosis in the caudal portion by cutting section using those materials placed for external observation.

Rhinoraja kujiensis:- In Fig. 41 K, we can see that the vestigial elements, which were said by EWALT (1888, p. 543) to be the primary club, are in process of conversion into the electric cup from the muscle fibers. It should be noticed herewith that the vestiges are not developed in the distal tip of the tail, and that only a small number of the vestiges are feebly seen in the portion falling far before the tip, and a

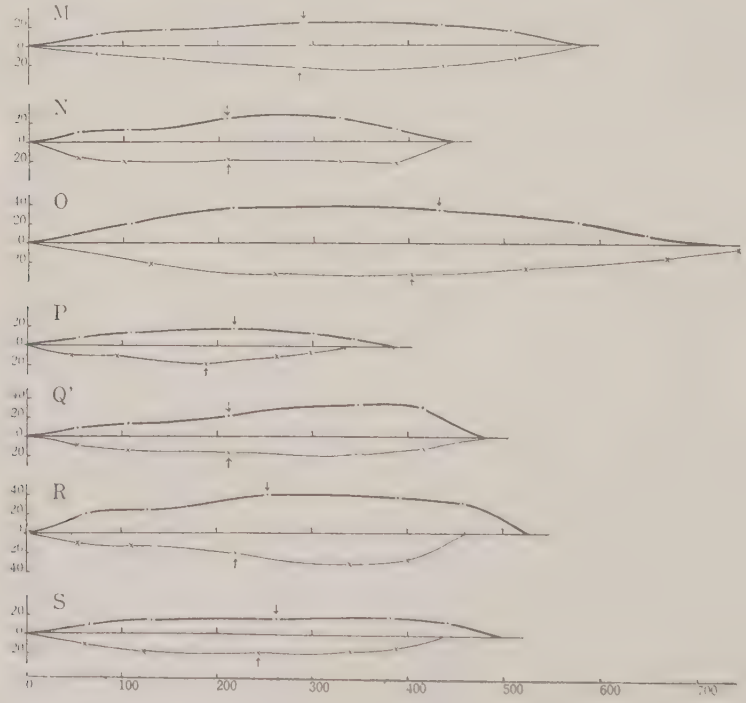

Fig. 39. Curves showing the distribution of electric elements in an organ of six forms of the southern members. Upper in each figure is regarded to that in the male, the lower in the female. Method of illustration is the same as in Fig. 38. M, *Raja kenojei*, N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q', *R. porosa tobae*; R, *R. fusca*; S, *R. schmidti*.

large number of cups in some advanced stage of development are found anteriorly in front of the 2nd dorsal fin. Such being the case, none of the electric elements which might be converted from the muscle fibers is found to rise in the caudal tip, which shows that the tip is in the representative state of shriveling and dropping-out of the tissue therein.

Supposing from these facts which were introduced from ontogenetic development of the electric elements in the caudal tip and of the reduction of the portion in the later embryo of this species, we may conceive that the reduction of the distal portion of the tail may have close relation to the development of the electric organ.

On the other hand, when the facts given above are compared with the metamorphosis observed in the external of the tail (p. 69; Fig. 34), that the occurrance of the vestigial elements seems to have extended *in situ* to the portion indicated by the arrow in that figure. Further, it will be evident to observe the facts

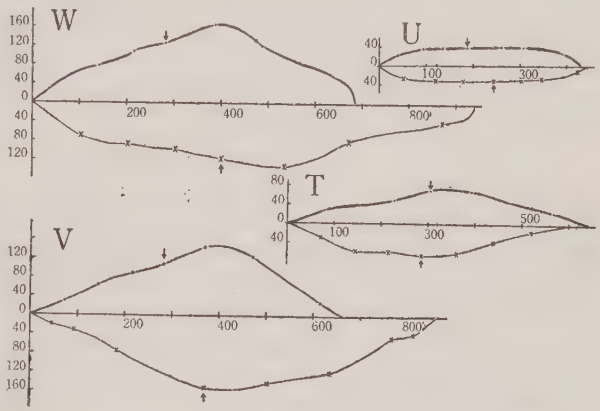

Fig. 40. Curves showing the distribution of electric elements in an organ of four forms of the southern members. Method of illustration is the same as in Fig. 38. T, *Raja tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

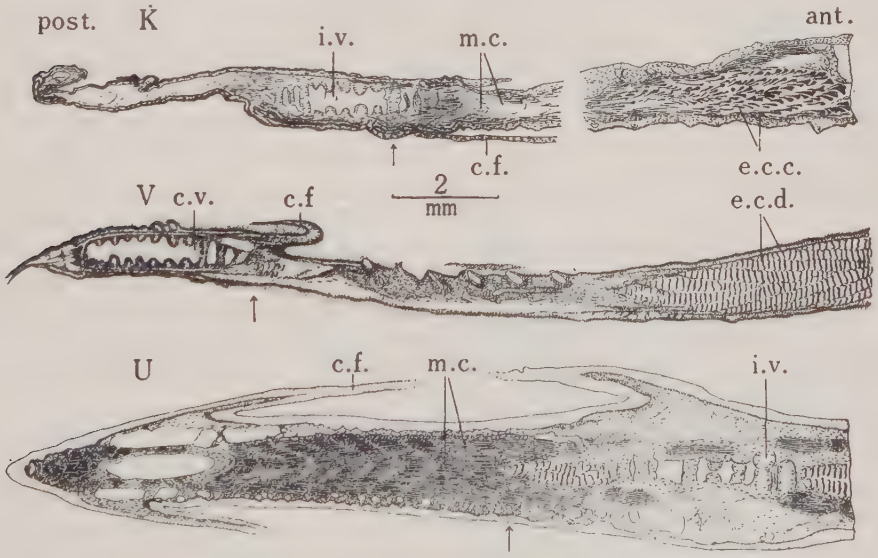

Fig. 41. Longitudinal vertical sections of the caudal tips in the two representatives of the electric organs of the post embryos, especially showing the development of the cup-form elements which are in conversion from the muscle fibres falling far from the tip in K (*Rhinoraja kujiensis*), and that of disc-form ones in U (*Raja pulchra*) and V (*Raja macrocauda*), in which exuviation and reduction of the caudal tip are in progress to form the elements from the muscle fibres falling far from the distal tip. The arrow indicates the posteriormost part where the electric elements are distinct in its development (sea also Fig. 34). ant., anterior; c. f., caudal fin; e. c. c., electric cone of the cup-form elements; e. c. d., electric cone of the disc-form elements; i. v., incipients of the vertebrae; m. c., muscle cone; post., posterior.

that the portion of shriveling and dropping-out in the distal portion of tail is naked from any armatures.

It should be expected from these evidence mentioned that the long caudal tip might be a purely temporary organ which has been developed during post-larval life, and disappears as the young grows or even before, and that this phenomenon may be correlated not only with its sheer necessity for their bottom life but also with the development of its electric organ.

Raja pulchra:- The post-embryo used in this study is the same material with what was referred to the external (cf. Fig. 34 U). The electric organ in the relatively long caudal portion in question is found to lie posteriorly near the middle of the portion when cut in the same way with the preceding species. We can evidently observe that the electric elements are in complete development, and that the organ is decidedly distinguished from its surrounding tissues. It may hence be said in this case, as has already been mentioned by EWALT(1892, p. 403) that the organ may reach to almost complete development in the latest embryo, followed by the reduction of the rear portion which continues for some time till after the embryo has emerged from the egg-capsule (U in Fig. 41).

Raja macrocauda:- Noteworthy in this specimen is that the great length of the caudal portion is still found remaining in the young stage (V in Fig. 34). And, the posterior extremity of the electric organ is found to exist nearer to the end of second dorsal than to the tip of the tail (cf. V in Fig. 41). However, it must be noted herewith that the specimen is thought to indicate more precocious features in its outward appearence than does *R. pulchra* mentioned above though the specimen was secured in the open sea. From this fact the reduction of the long caudal portion may continue for some time after the young has begun to get its own living.

A specimen of this species at its more advanced stage shows the scar marked on the extremity of the long caudal portion, where the organ is still falling far from the distal tip of the tail (V_2 in Fig. 34).

Raja porosa tobae:- The extremity of the electric organ is also found to exist, lying nearer to the end of second dorsal than to the tip of tail, which is still long and tapered in shape. A specimen in somewhat metamorphosed stage has some interesting feature in its caudal tip. The reduction in the caudal tip, as seen in Fig. 34 Q′, is in the stage of dropping-out by shrinking and segmenting into several pieces. The electric organ is, of course, found to lie not reaching to the extremity of the tail, as expected from the foregoing facts (cf. Fig. 34 Q'_{1-3}).

Taking those facts into consideration which show the relation between the reduction of the caudal tip and the degree of development of the electric organ, we may safely infer that, though there are more or less difference in the developmental history of the organs between the northern and the southern forms as well as between species, the later embryonic development of the organ may have caused the reduction or dropping-out of the caudal portion. Such hypothetical conception of the reduction in the tail as are formed from those ontogenical developments in relation to the degrees of development of the electric organ must not be overlook in finding clue to some systematic significance of the tail in rajid fishes.

Discussion

1). Use of the tail in taxonomy

On the basis of some important characteristics in both external and internal parts

of the tail observed in this study, the present writer has made an analytical key to species or groups of species of the Japanese rajids, in order to make out the systematic significance of the tail of the fish. Of course, the tails of rajids bear some important characters, such as the patterns of distribution of the placoid scales and the number of vertebrae. From this key, however, one may clearly grasp in classifying the fish the use of the tail to them, and the writer has later on clarified all those characteristics revealed in the tail for the students to rely on in determing species in the systematic part of the present investigation.

1a. Tail usually long, round-type in external view with some exceptions; dermal fold on both sides of the tail distinct posteriorly, but anteriorly it reaches to midway of the tail, falling far behind from the root except for the species **A**; electric organ more or less developed on both sides of the tail, characterized by constituting the cup-form elements.

2a. Tail very long, 0.8 to 1.2 times as long as the width of disc even in the adult; electric organ small or moderate in its development, lying from distal tip to far rearward of middle point of tail.

3a. Tail much more elongated, always longer than length of disc; electric organ less developed, polygonal in cross view of main portion, falling anteriorly far rearward from the middle of tail.

4a. Dermal fold on both sides of tail distinct throughout whole length of the tail; electric elements smallest in number, enumerated about 3400 in an organ, and the elements are more numerous in procaudal than in precaudal portion .... *Breviraja tobitukai* (**A** in Figs. 30 and 38)

4b. Dermal fold on both sides of tail developed only on posterior half; electric elements involved in an organ somewhat more numerous than in the preceding, enumerating more than 5000 in number; number of elements in the precaudal more numerous than that in the procaudal ..... *Rhinoraja odai* (**J** in Figs. 31, 35 and 38); *Rh. kujiensis* (**K** in Figs. 35 and 38); *Rh. longicauda* (**L** in Figs. 35 and 38)

3b. Tail rather long, almost as long as or slightly longer or shorter than length of disc; electric organ more or less well developed than that in the precedings, triangular or roundish in cross view, scarcely extending forward halfway to base of tail.

5a. In adult, tail about as long as or slightly longer than length of disc; electric organ rather small, the part lying in precaudal portion one-third time shorter than the length of that portion; number of electric elements in the precaudal except for species **D**, more numerous than in procaudal, but is reverse in species **D** ..... *Breviraja isotrachys* (**B** in Figs. 35 and 38); *B. trachouros* (**C** in Figs. 35 and 38); *B. abasiriensis* (**D** in Figs. 35 and 38)

5b. In adult, tail slightly shorter than, or nearly equal to, length of disc; electric organ somewhat advanced in its development, the length lying in the precaudal almost one-third time as long as that portion; electric elements in the precaudal slightly more numerous than in the procaudal ..... *Breviraja diplotaenia* (**E** in Figs. 35 and 38); *B. matsubarai* (**F** in Figs. 35 and 38); *B. aleutica* (**G** in Figs. 35 and 38)

2b. Tail short, depressed-type, about 1.50 to 1.75 times as long as width of disc; electric organ much more developed than in 2a, round in cross section of the main portion, extending from distal tip to near or beyond half way to base of tail; electric elements much more numerous in the northern members, the ratio of precaudal ones

to procaudal ones more than 1.5 times .....
Breviraja parmifera (H in Figs. 35, 38 and 68); *B. smirnovi smirnovi* (I in Figs. 35, 38 and 68); *B. smirnovi ankasube* (I′ in Figs. 38 and 69)

1b. Tail relatively short, depressed-type in external view; dermal fold on both sides of tail more or less distinct, covering from base of tail to the distal tip; electric organ characterized by having disc-form elements.

6a. In adult, tail less reduced, about 1.2 to 1.6 times as long as width of disc; electric organ very small or moderately developed, running from distal tip to near or far behind the center of posterior ends of pelvic fins.

7a. Procaudal part of tail relatively long; electric organ very small, falling the anterior tip far from posterior ends of pelvic fins.

8a. Procaudal portion more than one-third time as long as tail, holding more than half the length of electric organ ..... *Raja hollandi* (O in Figs. 36, 39 and 75); *R. macrophthalma* (P in Figs. 36, 39 and 76)

8b. Procaudal portion as long as or a little longer than half the length of tail, holding about one-half the length of electric organ ..... *Raja kenojei* (M in Figs. 36, 39 and 73); *R. schmidti* (S in Figs. 37, 39 and 81)

7b. Procaudal portion moderately reduced in length; electric organ moderately developed, reaches or extending to near posterior ends of pelvic fins, the length almost half as long as tail ..... *Raja acutispina* (N in Figs. 36, 39 and 74); *R. porosa meerdervoorti* (Q in Figs. 36, 39 and 77); *R. porosa tobae* (Q′ in Figs. 36, 39, 79 and 80)

6b. In adult, tail more reduced, about 1.35 to 2.0 times as long as disc-width; electric organ relatively large or enormously well developed, covering from distal tip of tail to near or far beyond posterior ends of pelvic fins.

9a. Procaudal length of tail somewhat longer than or nearly as long as one-half length of tail measured rearward from posterior ends of pelvic fin; electric organ relatively large, reaches to posterior ends of pelvic fins (female) or farther beyond (male) ..... *Raja fusca* (R in Figs. 36, 39 and 80); *R. tengu* (T in Figs. 37, 40, 81 and 82)

9b. Procaudal portion of tail longer or much shorter than one-half length of tail measured posteriorly from posterior ends of pelvic fins; electric organ more or much more developed, reaching anteriorly to, or beyond posterior ends of pelvic fins in both sexes.

10a. Procaudal portion more than half as long as tail measured posteriorly from posterior ends of pelvic fins; electric organ better developed with two subequal portions divided .....
..... *Raja pulchra* (U in Figs. 30, 37, 40, 83 and 84)

10b. Procaudal portion much shorter than the half length of tail measured posteriorly from posterior ends of pelvic fins; electric orgn much better developed in size in southern members, extending beyond distal ends of pelvic fins.

11a. Procaudal portion nearly as long as or shorter than one-third length of tail; distal portion of tail reduced into small flap of the caudal fin; electric organ developed in enormous size, occupying almost whole room of muscular tissue in the tail .....
..... *Raja macrocauda* (V in Figs. 37, 40, 85 and 85)

11b. Procaudal portion more than one-third times as long as tail; distal portion of tail somewhat long, holding distinct caudal fin .....

..... *Raja gigas* (W in Figs. 37, 40, 84 and 86)

2). **Consideration on the utility of the tail**

In general, forward movement of the body in the elasmobranch fish may largely be classified in two fundamental types, one is found in the shark and called caudal-type, and the other is found in the batoid fish and called pectoral-type. In skates and rays, the caudal portion is so atrophied that the fin may act as a rudder, but not as a powerful propelling organ. In fact, the dorsal fins are usually falling and ensuing far back on the tail, and the caudal fin usually keeps up its position with only a small flap, which almost disappears in some species. These features found in the tail of rajid fishes may be outstanding negative specialization toward diminution in opposition to positive specialization developed with pectoral fins. But a point of great importance is the presence of the electric organ which might subserve for the rajids some such favors as special function. The present writer has given a working hypothesis on the natural function of the electric organ (ISHIYAMA, 1955).

In the present scheme, the writer will discuss further from ontogenical and genealogical viewpoints the use of the tail relating principally to the correlation found between the reduction in tail and the degrees of development of the electric organ, though it still remains to be proved how the skate's organ subserves in practice.

Judging from the characteristics observed upon morphological and embryological evidences in the tail of rajid fishes, the tail has two different uses. One is its original function, or we should rather say fundamental use, for movement of the body. The other, inferred from genealogical evidences of the organ is the tail being used as a defensive weapon responsible for special external stimuli. Of these two hypothized functions of the tail, the former may be believed to be still remaining in a greater number of tails of the round-type, in which almost all members in the northern form are included. But, since the depressed-type, to which the southern form and some of the northern one belong, has been reduced in its length in greater or less degree, its tail may have been kept at more retard than that of the round-type in its original function. At any rate, we can surely believe that the effective power in the original function may be gradually increased from the distal portion to the base of the tail, where the muscular tissue is great.

On the other hand, a special function of the tail may be presumed from the fact which has been confirmed by physiological studies of the electric organs of certain skates (ROBIN, 1865; SANDERSON and GOTCH, 1888). The existence of rather weak electrical shock discharged from the skate's organ at the distal end of the tail seems to have some use for orientation. In fact, the electromotive force can be increased from the anterior portion where the organ lies rearward to the tip. In this case, taking into consideration all the facts given in the foregoing chapters showing the relations between the reduction or dropping-out of the tip of tail and the degree of development of the electric organ, and between the relative length of the tail and the degrees of development of the electric organ, we cannot but conceive that the organ must have some causal relation to the growth of the tail. In other words, the electric organ may be a special organ, which is presumably very useful for the conservation of the activity of the tail, probably necessary for the bottom living.

If this is really the case, the tail may have two different roles: its original function of propelling the body and a function as the special organ or as a special feeler. This concept that the original and the special functions of the tail form a reciprocal relation may be understandable from ontogenical and genealogical viewpoints mentioned above.

Further, a evidence that the electric organ grows in its weight as the body does (according to EWALT, 1892; p. 402) with its sudden increase in the skate when it attains its maturity may, therefore, suggest that the organ may have some use in the probable strife for existence among the species.

Though it may be still now impossible to interpret the real biological function of such a peculiar organ in the tail of the skate, the hypothetical view so far mentioned may imaginatively be extended to our explanations of the tail as an organ of avoiding inter- and intraspecific competition or as that of species selection rather than a defensive weapon against natural enemies' attack from behind the body. Likelihood is that the skate's organ may act a role similar to what has generally been considered about the natural function of the luminescent organ in the fish and other animals*).

3). Consideration of the differentiation of the tail

Having examined comparatively important features in both external and internal of the tail of Japanese rajid fishes, the present writer has concentrated his particular attention on the following points, with a view to arriving at a conclusive opinion on the present scheme, thus; i) general shape of the tail, ii) relative length of the tail and its change with growth of the body, iii) structural characteristics of the electric organ, and iv) reduction of the tail-length or exuviation of the caudal tip in relation to degree of development of the electric organ.

On the basis of i) to iii) categories mentioned above, the rajid fishes can be divided in two main groups. But the phyletic relationship of the two groups is so diversified in their courses of differentiation that it may be difficult to interpret reasonably such a complex structure. However, in order to solve this puzzle, the writer has considered the problem within the limits of the following bases helped by some working hypotheses given in the preceding scheme.

(i). From both phylogenical and ontogenical viewpoints of the batoid fishes, it is generally believed that the long tail of the round-type, which appears to be its primary modification in the shark, may be considered to be more primitive than the short tail of the depressed-type. Consequently, the so-called southern form may be more specialized than the northern form in respect to the general shape and relative length of the tail. Similarly, the tail in the species **H** and **I** (**I'**) may be in more advanced condition, and the species **A**, **J**, **K** and **L** may be less specialized, in the northern form.

(ii). In comparison of ontogenetic change of the relative ratio of the tail with the growth of the body, the northern form appears to show congeneric trend with linear relation without any sexual difference even in the adult, but the southern form may be divided in two groups in this respect, viz., one, which involve the six species (**M**, **N**, **O**, **P**, **Q** and **S**), shows sexual difference in the adult to some extent, representing curvilinear relation, and the other, exemplified by the five species (**R**, **T**, **U**, **V** and **W**) reveals imperceptible sexual difference with curvilinear relation.

(iii). As a hypothetical conception on successive changes of relative length of the tail in both ontogenical and linealogical series in relation to the degree of development of the electric organ which may have some causal relation to the reduction of the tail or exuviation of the caudal tip, we can suppose that the existence of relatively long tail with relatively small electric organ may be considered primitive than that of relatively short tail with large electric organ.

Granting that these views were true, purely hypothetical as it is, the phyletic

* On this matter, the present writer will give an accounts in future.

relationship in the two major groups of Japanese rajids may be expected to be through the two confronting features of each species, i.e. relative length of the tail and numerical ratio of the electric elements between the precaudal and procaudal portions.

Conclusively, the following figure obtained from these two morphometric evidences in the tail of each species shows systematic relationship in the different groups of Japanese rajids, concerning the successive changes of relative length of the tail and degree of development of the electric organ (Fig. 42).

It is worthy of special mention that the figure coincides fairly well with the inter-relationship deduced from the features of the clasper of this group of the fish (cf. Fig. 21).

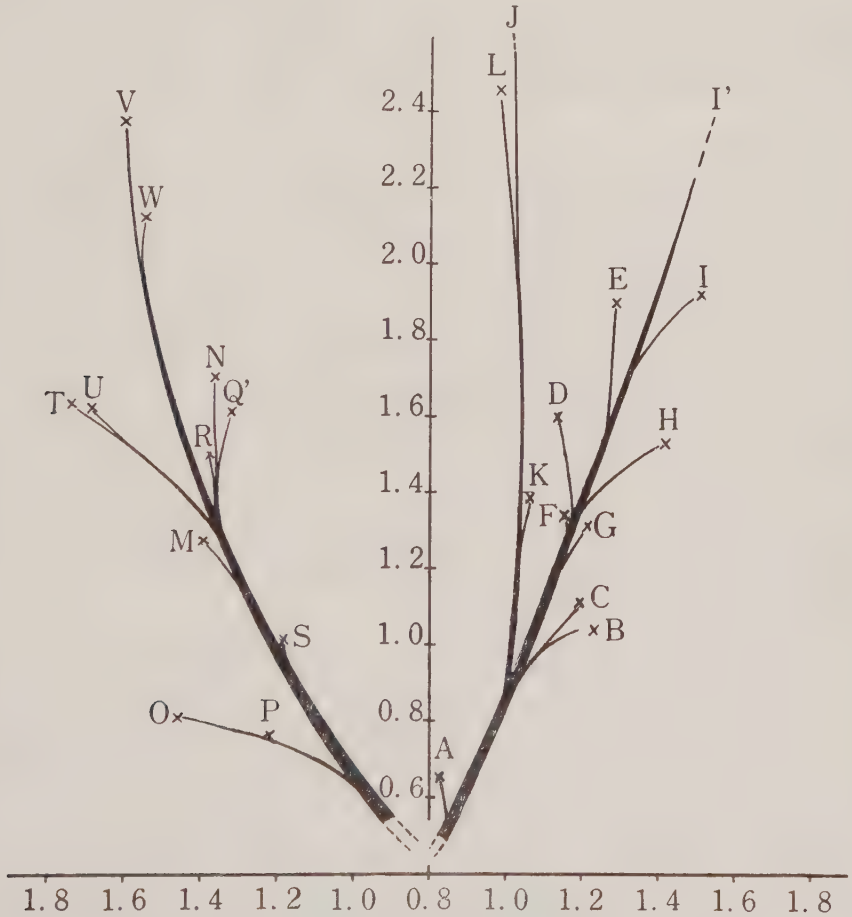

Fig. 42. Supposed relationships based on ratios of the length of tail in disc-width (horizontal axis) and of the number of electric elements of precaudal portion in procaudal ones (vertical axis), especially showing parallel evolution in the two major groups of Japanese rajids in respect to the two morphometric importances. A, *Breviraja tobitukai;* B, *B. isotrachys;* C, *B. trachouros;* D, *B. abasiriensis;* E, *B. diplotaenia;* F, *B. matsubarai;* G, *B. aleutica;* H, *B. parmifera;* I, *B. smirnovi sminovi;* I', *B. smirnovi ankasube;* J, *Rhinoraja odai;* K, *Rh. kujiensis;* L, *Rh. longicauda;* M, *Raja kenojei,* N, *R. acutispina,* O, *R. hollandi;* P, *R. macrophthalma;* Q, *R. porosa meerdervoorti,* R, *R. fusca;* S, *R. schmidti;* T, *R. tengu;* U, *R. pulchra;* V, *R. macrocauda;* W, *R. gigas.*

This fact may enable us to infer that the characteristics of the tail are highly valued in the systematic classification of rajid fishes.

C. Vertebrae

1. Description in general

The vertebral characters in elasmobranch fishes have been subjects of discussion from the past, being used in the taxonomy as well as in the phylogeny of various groups of the fish (HASSE, 1879 ; REGAN, 1906 ; WHITE, 1936). HASSE has distinguished three types of vertebrae in the Elasmobranchii, based principally on the structure and the condition of calcification, thus: the cyclospondylic, the asterospondylic and the tectospondylic. Of these, the last type of vertebrae, which involves the batoid fishes, is characterized by having centrum with numerous concentric calcified cones*). We, in general, agree with the above critique for the separation of such three types of calcification.

In all batoids the larger part of the anterior region of the vertebral column has a solid vertebral plate fused, to which the scapular portion of the shoulder girdle is attached. Yet many differences have been noticed in the form of the plate within groups of the batoids (GARMAN, 1913), and the character is not so remarkably different among Japanese rajids dealt with. The vertebral centra of rajids are gradually reduced in size anteriorly, being embedded in the vertebral plate. Posteriorly, they extend near the tip of the tail, where the segmentation is incomplete owing to the reduction in its distal portion, as mentioned elsewhere (cf. Fig. 41).

The present writer has given an account of Japanese rajids on the number of the vertebrae divided into three groups, as follows; abdominal, precaudal and procaudal (ISHIYAMA, 1952). In the present study, he has made a analytical comparison between counts in the abdominal and precaudal regions of all the species. But the procaudal vertebrae are kept outside of this comparison due to the inclusion of the incomplete segmentation of the distal portion. The reason why the boundary between precaudal and procaudal regions can be determined arises at this point, and the writer has adopted the following hypothesis to interpret this question.

It has generally been widely assumed that the modification in the feature of the caudal vertebrae in some elasmobranchs may have come about for greater freedom and strength of movement in the caudal portion (RIDEWOOD, 1899 ; REGAN, 1906 ; DANIEL, 1928). In fact, according to CAMPBELL (1951), the undulatory pattern of movement in the tail of *Rhinobatus productus* has been proved to have a different threshold responsible for external stimuli between anterior and posterior portions of the first dorsal fin. Further, the present writer(1955) mentioned in the Japanese rajids that the distributional pattern of the electric elements markedly changes starting at the insertion of first dorsal fin. On the basis of these facts it seems reasonable that the subdivision of the caudal vertebrae in this group of fish may be justifiable according to the functional meaning.

At any rate, it is rather difficult to count the vertebrae covering the two region,**) and counts vary in some degree in the same species. Nevertheless, the present writer has ascertained that noticeable differences are found between the counts in the two

* Of this matter, the present author has given several accounts (ISHIYAMA, 1951 [a,b], '55, '56), where he claimed that the concentric calcified rings of the centrum of the vertebra in some rajids are regarded as annual growth rings as is observed in many teleosts, and also see p. 119 in this article.

**The counts were made by means of X-rays or dissection.

regions of the vertebrae, which has enabled us to separate the Japanese rajids into two phyletic groups.

2. Comparison of the vertebral counts

By the total number of the vertebrae of the two regions, the two groups, one with a larger count about 90 and above, and the other with a fewer counts, less than 90, are regarded, respectively, to the northern and southern forms. In comparing the two series of vertebral counts thus divided, the writer has scrutinized the fish in regard to the counts for the purpose of subdividing it into four groups. As seen in Table 9, the differences between those two groups in the two series of counts are more pronounced in the precaudal than in the abdominal groups. More exactly, the number of abdominal vertebrae shows less magnitude in its range of variation than that of the precaudal ones. Further, it should be noticed that the tendency in the variation of vertebral counts in the two regions of the backbone classifed shows a regularity in the differences between those counts in species or groups of species.

Table 9. Counts of abdominal and precaudal vertebrae in Japanese rajids, especially showing smaller counts with less variability in the abdominal vertebrae than in the precaudal ones. Number of specimens examined of each species is parenthesized. C. V., coefficient of variation; S. D., standard deviation; for other abbreviations, see Fig. 43.

Species	Abdominal vertebrae		Precaudal vertebrae		Species	Abdominal vertebrae		Precaudal vertebrae	
	range	mean±S. D.	range	mean±S. D.		range	mean±S. D.	range	mean±S. D.
A (11)	24—27	25.4±0.78	63—70	65.6±1.90	M (6)	27—28	28.3±0.74	44—47	44.8±0.69
B (10)	34—40	36.1±1.61	73—82	77.4±2.83	N (5)	26—29	27.4±1.02	20—42	41.2±0.97
C (9)	32—36	33.4±1.06	71—77	74.3±1.88	O (5)	28—29	28.4±0.49	38—42	40.8±2.13
D (5)	31—33	32.4±1.02	66—70	67.6±1.58	P (5)	25—26	25.4±0.49	38—43	40.4±1.87
E (11)	31—37	33.6±1.50	70—74	71.1±1.62	Q, Q′(13)	25—30	27.3±1.45	36—43	40.1±1.85
F (5)	34—36	35.0±1.00	71—73	71.8±0.75	R (5)	28—29	28.8±0.40	29—43	41.0±1.41
G (7)	35—38	36.0±1.19	69—74	70.8±1.82	S (5)	27—29	28.0±0.63	42—45	43.4±1.01
H (1)	39		82		T (5)	31—32	31.4±0.15	46—50	47.6±1.35
I, I′(8)	35—40	37.4±1.86	83—88	85.0±2.05	U (7)	30—32	31.2±1.03	38—42	39.1±1.16
J (10)	33—36	34.1±1.04	85—91	88.4±2.1	V (8)	30—33	31.2±1.17	53—59	55.3±1.98
K (8)	33—38	35.1±1.76	76—83	79.3±2.33	W (4)	30—34	32.5±1.50	59—61	60.0±1.00
L (7)	30—32	30.5±0.73	74—80	75.5±2.06					
Total range	24—40		63—91		Total range	25—34		36—61	
C. V. (%)	11.5		9.8		C. V. (%)	7.9		11.5	

It will be seen from these figures that the abdominal counts may be considered less variable than precaudal ones in successive changes from species to species.

The Japanese rajids thus may be classified into four groups of species on the basis of the counts of the precaudal vertebrae, viz., those with about 75 and below, those with about 75 and above which can be related to the two groups of the northern form, those with about 45 and below, and those with about 45 and above which can be related to the southern form. The following five species **A**, **D**, **E**, **F** and **G** belong to the first group. The second includes the following seven species **B**, **C**, **H**, **I** (**I′**), **J**, **K** and **L**. The third includes seven species **N**, **O**, **P**, **Q** (**Q′**), **R**, **S** and **U**. The remaining four species **M**, **T**, **V** and **W** are referred to the fourth group.

As indicated in Fig. 44 accompanying the above description, successive changes in vertebral counts of precaudal groups seem to indicate some tendency in the respective group of species.

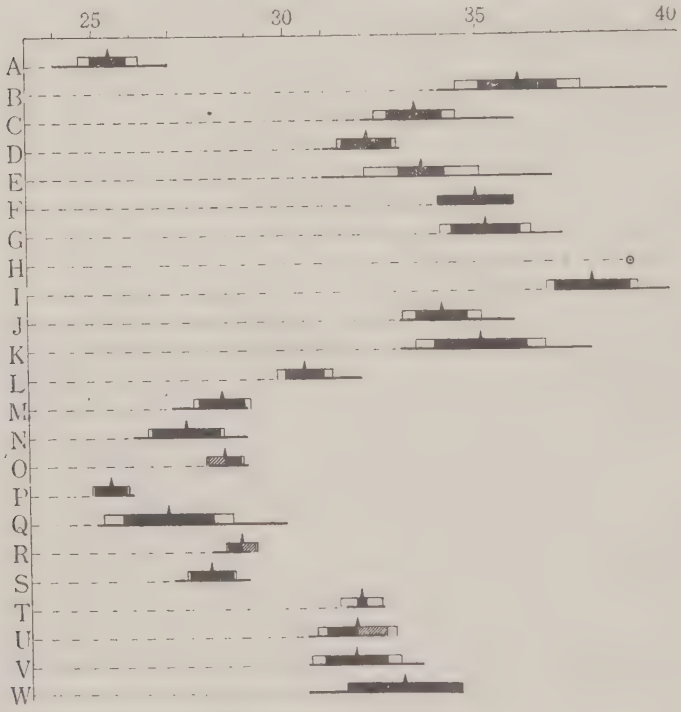

Fig. 43. Showing variation in number of abdominal vertebrae of Japanese rajids. In each species, the horizontal heavy line indicates total variation of the sample; the mean is indicated by a small triangle which projects upward; the solid area is the extent of 2 standard errors on each side of the mean; the hollow area delimits one standard deviation on each side of the mean; the hatched area indicates 2 standard errors in case the extreme range of total variation is yet smaller than the extent of 2 standard error; the guide line is broken. A, *Breviraja tobitukai*; B, *B. isotrachys*; C, *B. trachouros*; D, *B. abasiriensis*; E, *B. diplotaenia*; F, *B. matsubarai*; G, *B. aleutica*; H, *B. parmifera*; I, *B. smirnovi smirnovi* including *smirnovi ankasube*; J, *Rhinoraja odai*; K, *Rh. kujiensis*; L, *Rh. longicauda*; M, *Raja kenojei*; N, *R. acutispina*; O, *R. hollandi*; P, *R. macrophthalma*; Q, *R. porosa meerdervoorti* including *porosa tobae*; R, *R. fusca*; S, *R. schmidti*; T, *R. tengu*; U, *R. pulchra*; V, *R. macrocauda*; W, *R. gigas*.

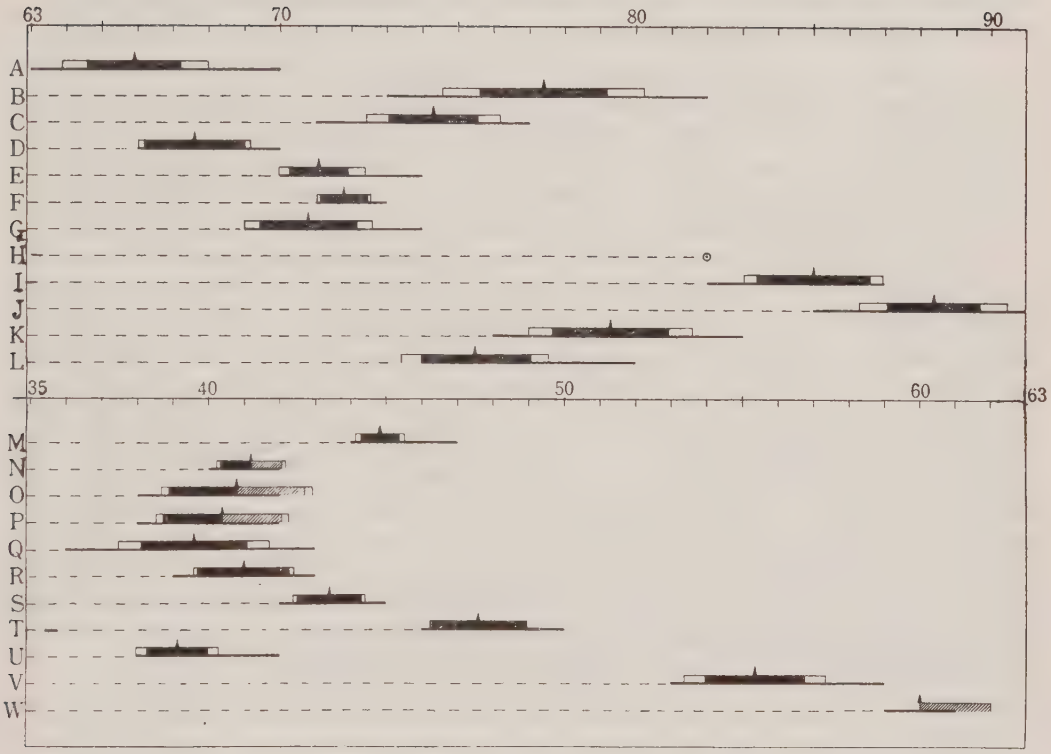

Fig. 44. Showing variation in number of precaudal vertebrae of Japanese rajids. The graph is illustrated by the same method as in case of Fig. 43. In this Fig., especially in comparison with the preceding Fig., the range of transpecific variation is distinct between the two major forms of the rajids with a boundary of about 60 in number of the vertebrae. For abbreviations, see Fig. 43.

3. Discussion

1). Use of the vertebral counts in taxonomy

It is a well known fact in the teleosts that the variation in the vertebral counts tends to change with more or less regularity according to the physical condition of the environments where the fish inhabits. The character, on the other hand, is usually found to be a fundamental phylogenic rather than physiological one within the limits of the variations. In distinguishing the character either phenotypically or genotypically, the writer believes that the characteristics in question in the case of our rajids may serve at least to provide a designation of subgeneric ranks, which were classed into four groups on the basis of precaudal counts aforementioned. Nevertheless, the counts cannot be used for establishing a specific demarcation since the character shows gradual change from species to species, overlapping some frequency in each subgenus.

When these characteristics are examined, the differences between groups of species seem valid for the taxonomy and phylogeny of Japanese rajid fishes, because such important features as found in their claspers are generally parallel with the traits

which are maintained in this character (cf. Fig. 21). Whereas, as may be expected, the counts do not appear as a specific constant, but are generally useful as a partial index of the overall fundamental character.

2). **Variation in the vertebral counts in relation to geographical distribution**

Fish taxonomists have accumulated a good deal of useful knowledge on this subject in establishing a modern species concept, notably in teleosts which inhabit different localities and which have evolved many differentiated forms. But we possess much less literature on this subject, since the best research has not dealt with elasmobranch fishes.

It may obviously be assumed from the present work that the colder water members of Japanese rajids have more numerous vertebrae than the warmer water representatives. Further, this phenomenon seems to have some relationship to their geographical distribution as is the case with various teleosts, in which the number of vertebrae depends upon the physico-chemical condition at the time when vertebral organization takes place. Applying the theory in this case, we may consider the relation between the water temperature at which the adult females with egg-capsules were caught and their vertebral counts (Fig. 45). As indicated in this figure there seems to be a positive correlation between the numbers of abdominal and of precaudal vertebrae and the water temperature where those parent females were caught. Further, from this figure it is also apparent that the precaudal rather than abdominal segments of the backbone vary from species to species, and seem to show the decrease of the vertebral counts with the increase of temperature. Although the precaudal counts may be used as a subgeneric character, as already mentioned in the preceding section, the character seems to correlate more or less with its geographic distribution.

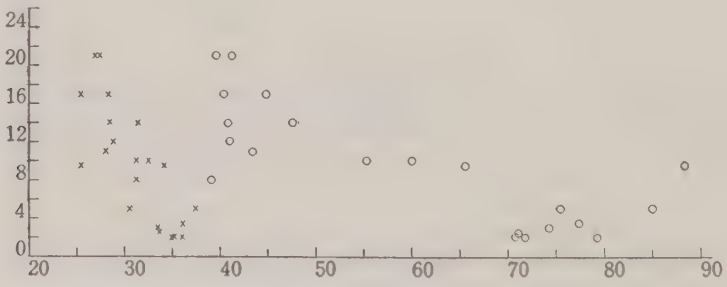

Fig. 45. Showing relationships between the water temperature where the parent females of 21 forms of Japanese rajids were caught and the numbers of abdominal and of precaudal vertebrae. Temperature (°c), ordinate; vertebral counts, abscissa; cross, abdominal; circle, precaudal.

Another aspect of variation in the character concerns the question of the range of valency with which the two forms do not intermingle between each other.

Thus, the character of the diverse forms that constitute Japanese rajids suggests two main phyletic lines, but the interpretation of this matter cannot be regarded as certain.

3). **Correlation between number of vertebrae and other internal character**

In the present item the writer has only dealt with the relation between the number of vertebrae and that of turn of the intestinal valves. It is found that the species having a relatively higher number of vertebrae tend on the whole to have larger number of turns of the intestinal valves, and this parallelism between the two characters

seems to be dependent on the condition where the meristic organization takes place. Further, the degree of correlation between the number of the abdominal vertebrae and that of the intestinal valves is considered to be greater than that between the number of the precaudal ones and the number of the intestinal valves (Fig. 46). The writer must make a plausible interpretation of these facts in the future, taking up a good many more experiments. But as to the reason why successive changes in number of the vertebrae are attributed more to genealogical pedigree than to adaptive process, as compared with the changes in the intestinal valves, the present writer argues in favour of the following evidence. It is clearly found in the foregoing description that the

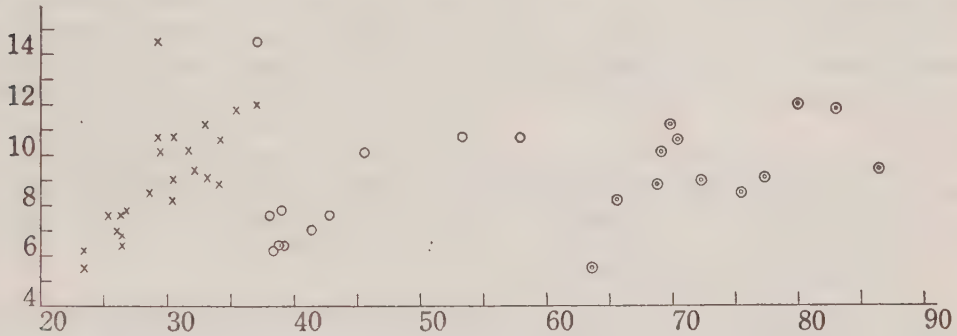

Fig. 46. Relationships between mean value in number of the intestinal valves (ordinate) and those in the abdominal and precaudal vertebrae (abscissa), especially showing parallel relation between numbers of the valves and of the abdominal vertebrae (cross). Circle and double circle represent precaudal vertebrae of southern and northern form, respectively.

number of vertebrae is divided into two series of groups of species, which are divergently radiated with a boundary of 60 in the number of precaudal vertebrae. The number of intestinal valves, on the contrary, varies in direct proportion between the two groups of Japanese rajids, from five to thirteen or fifteen, of the number of the valves (cf. Table 10). Such being the case, the present writer can safely affirm that the variations in number of the vertebrae in species or groups of species of Japanese rajids are indicated principally as phyletic pedigree rather than as adaptive differentiations.

In conclusion, therefore, the observed differences in the degree of gradational variability in the vertebral counts may have basically been caused by genetic factors on one hand and partly influenced with less regularity by the effect of the environmental conditions on the other.

d. Intestinal valves

1. Description in general

The knowledge of the spiral valves and its application to the taxonomy of Japanese rajids is scanty up to the present day, except for the findings made by the present writer (Ishiyama, 1952, '55). As regards the organ of the elasmobranchs, however, a number of valuable contributions have been given by several authors, such as Gegenbauer (1870), Parker (1879), Mayer (1897), Garman (1913) and White (1936, '37). White has classified the elasmobranchs into three types according to the manner of the spire of the valves, such as scroll, spiral and ring. Of the three, the spiral

type has been regarded as referable to the Heterodontea, the Squalea and the Platosomeae.

The number of turns or gyrations of the spiral valves of the fish varies greatly among the elasmobranchs as has already been noticed in the past. But, since the valves are thought to have developed from the typhlosoles of cyclostomes and invertebrates to increase the surface of the intestinal canal by which absorption and digestion of food take place, it would be assumed that the principle affecting the variation of number of the valves might be similar to that in the pyloric coeca of the teleosts. Whereas, actually the variation in the number of the spiral valves in any species is usually slight. Accordingly, it is the main purpose of the present study to obtain an adequate answer to the question whether or not the feature of the intestinal valves is useful for separating Japanese rajids into species or some groups. Further, the category so far used to separate, if possible, any form with considerable certainty will be considered to be valid or not depending on the phyletic meaning of the groups of the fish.

With regard to this organ, the present writer has examined particularly the features as well as the number of gyrations of the valves in different species, from a viewpoint of taxonomy, and drawn the conclusion on the differentiation of the organ.

2. Comparison of the intestinal valves

The intestinal valves in Japanese rajids are found to be of the "spiral type", according to the scheme given by WHITE, and the organ is made up of a very thin membrane covered with microscopic villi, excepting the species U, in which the valves are much thickened (U in Fig. 47).

So far as the present investigation is concerned, the number of gyrations of the valves varies 5 to 15 in Japanese rajids, the variation not being remarkable not only in the groups but also in the same species. It is worthy of mention here that the trend

Fig. 47. Spiral valves of the intestine in six forms of Japanese rajids, especially showing interspecific variations in features and in number of the valves based on which six groups were classed. A, *Breviraja tobitukai;* K, *Rhinoraja kujiensis;* I, *B. smirnovi smirnovi;* M, *Raja kenojei;* P, *R. macrophthalma;* U, *R. pulchra.* Scales represent 2 cm.

in fluctuation of the valves and the range in number has little difference between the northern and southern forms, though they vary much in several other characteristics mentioned elsewhere. Namely, the least number of valves among Japanese rajids thus far examined is found in species **A** of the northern form and in species **P** of the southern form, and the greatest number is found in the species **F**, **H**, **I** (**I'**) and **U**, ranging from 11 to 13 and from 14 to 15 in the respective form. Further, it appears that the number tends to increase from species to species in the northern form more rapidly than in the southern one. For 'convenience' sake Japanese rajids may be classed into six groups in respect to the number of valves: one with few valves (from 5 to 6), another with intermediate number of valves (from 8 to 9), and a third with numerous valves (from 10 to 13) in the northern form; a group with few valves (from 5 to 7), another with intermediate number of valves (from 8 to 10), and a third with numerous valves (from 11 to 15) in the southern form. These are respectively called here groups 1, 2, 3, 4, 5 and 6, which are to be assigned to the species belonging to each group (Table 10).

Table 10. Variation in number of the spiral valves of the intestine in Japanese rajids. Number of specimens examined in each species is parenthesized. S. D., standard deviation; other abbreviations, as follows: **A**, *Breviraja tobitukai*; **B**, *B. isotrachys*; **C**, *trachouros*; **D**, *B. abasiriensis*; **E**, *B. diplotaenia*; **F**, *B. matsubarai*; **G**. *B. aleutica*; **H**, *B. parmifera*; **I**, **I'**, *B. smirnovi smirnovi* including *smirnovi ankasube*; **J**, *Rhinoraja odai*; **K**, *Rh. kujiensis*; **L**, *Rh. longicauda*; **M**, *Raja kenojei*; **N**, *R. acutispina*; **O**, *R. hollandi*; **P**, *R. macrophthalma*; **Q**, **Q'**, *R. porosa meerdervoorti* including *porosa tobae*; **R**, *R. fusca*; **S**, *R. schmidti*; **T**, *R. tengu*; **U**, *R. pulchra*; **V**, *R. macrocauda*; **W**, *R. gigas*.

Species	Range	Mean ± S. D.	Group	Species	Range	Mean ± S. D.	Group
A (13)	5 — 6	5.5 ± 0.50	1	**M** (5)	7 — 8	7.6 ± 0.48	4
B (10)	10 — 11	10.6 ± 0.49	3	**N** (5)	5 — 7	6.4 ± 0.80	4
C (7)	8 — 10	9.0 ± 0.54	2	**O** (5)	6 — 7	6.8 ± 0.40	4
D (5)	8 — 9	8.2 ± 0.40	2	**P** (5)	5 — 7	6.2 ± 0.75	4
E (9)	10 — 11	10.2 ± 0.41	3	**Q**,**Q'**(12)	7 — 8	7.6 ± 0.47	4
F (5)	11 — 12	11.2 ± 0.40	3	**R** (5)	7 — 8	7.8 ± 0.40	4
G (5)	8 — 9	8.8 ± 0.40	2	**S** (5)	7	7.0 ± 0.0	4
H (1)	12		3	**T** (6)	9 — 11	10.1 ± 0.28	5
I, **I'**(6)	11 — 13	11.8 ± 0.89	3	**U** (6)	14 — 15	14.5 ± 0.15	6
J (5)	8 — 10	9.4 ± 0.80	3	**V** (8)	10 — 11	10.7 ± 0.18	5
K (7)	9 — 10	9.1 ± 0.35	2	**W** (7)	10 — 11	10.7 ± 0.14	5
L (6)	8 — 9	8.5 ± 0.50	2				
Total range	5 — 13			Total range	5 — 15		

3. Discussion

1). Use of number of the intestinal valves in taxonomy

Though considerable differences of the intestinal tract are expected in various physiological process and in relation to the correlated organs in the same species which ranges all over the world from tropics to the temperate zone, as RENSCH (1931) has shown in the intestinal tract, the characteristics related to nutrition have often been confirmed to indicate a taxonomic integrity in some groups of the teleosts (HUBBS and

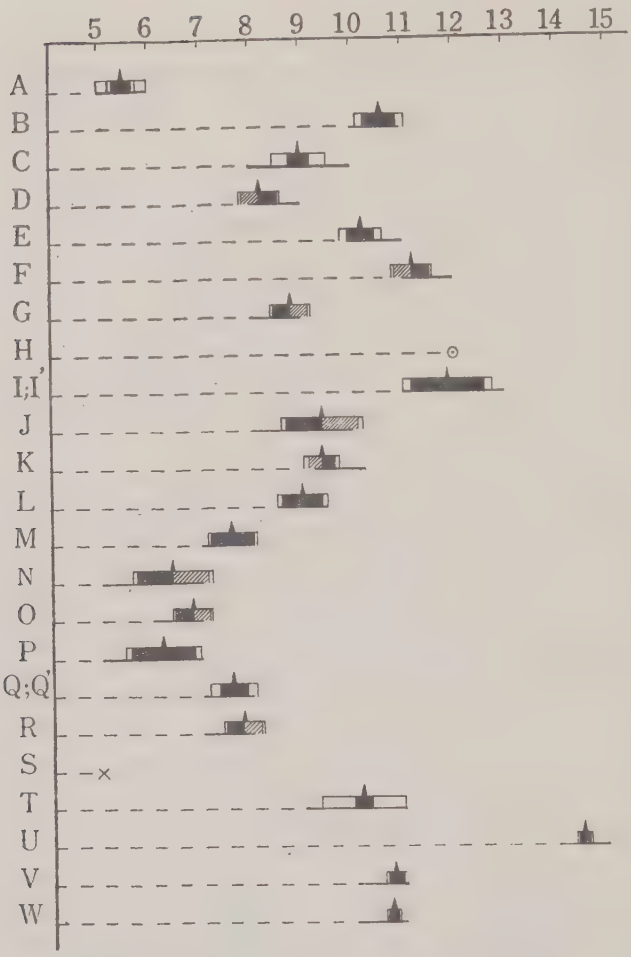

Fig. 48. Showing variation in number of the intestinal spiral valves of Japanese rajids. The graph is illustrated by the same method as in case of Fig. 42. In this Fig., especially in reference with the preceding table, the variations in both intra- and interspecific relations are less than those found in the number of vertebrae (Figs. 42 and 43). For abbreviations, see Table 10.

TURNER, 1939; BERNER, 1948; KAFUKU, 1952).

Differences in the number of the spiral valves of Japanese rajids are believed to be less important than other internal features in separating the genera or the species among the related forms because it has been discovered that the number must have the range of almost the same degree in many species, and varying degrees of overlapping or separation between any related species may fail to give a fine distinction if a lot of specimens are examined. But, it may be taken as certain that the species having such variant characteristics in question as those in the two species **A** and **U** can be used in clearly distinguishing their relatives.

2). **Geographical variation of the number of intestinal valves**

GEGENBAUR has pointed out that the small number of valves in *Chimaera*

monstrosa shows its being in a primitive condition. However, WHITE has stressed that this tendency may be a puzzle because of finding either a tendency toward multiplication or toward reduction in the derived families. And, she has suggested that the variation in the number of the valves in the spiral type, in which the Platosomeae is included, is paralleled with the variation in the heart valves.

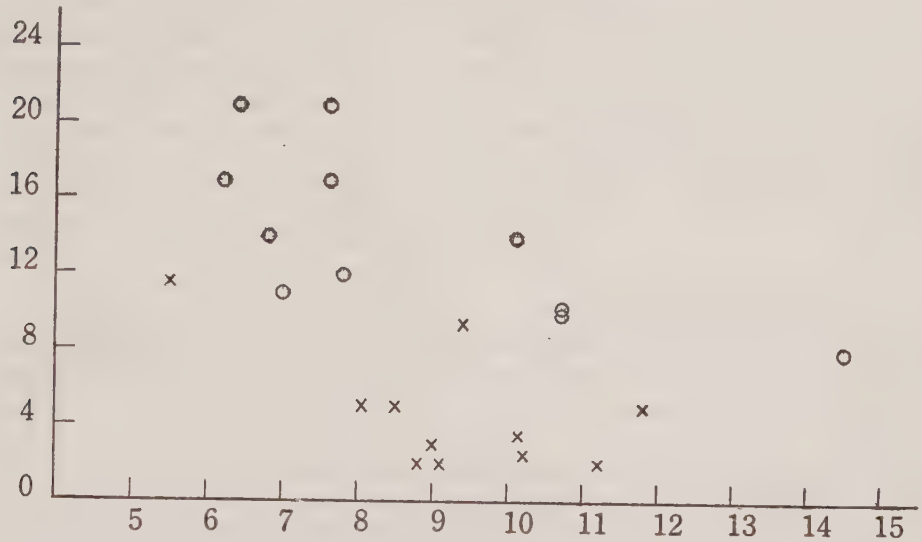

Fig. 49. Showing relationship between the mean number of spiral valves of the intestine and the water temperature (°c) where the parent females were caught. Temperature, ordinate; number of the valves, abscissa; cross and circle, the northern and southern form, respectively.

What is important for this discussion is whether such variation indicates the phyletic relation or merely an adaptive process. To solve this question the present author has examined the number of the intestinal valves of some fishes of the related families of batoid fishes obtained in our waters. Based on his examination with a comparative investigation of the variations in the features, the writer has come to the assumption that the variation in the number of the intestinal valves must be considered as a series of geographical characters which may have been acquired by the needed specialization in an adaptive zone.

As already mentioned in the preceding section and as shown in Table 10, Japanese rajids may be classified into six groups according to the number of valves, and the grouping is seemingly related to the geographical distribution of the fish. For example, the first group, which involves only one species **A** in the northern form and is characterized by having the smallest number of valves, is found only in the southernmost region, as stated elsewhere. The second and the third groups, which involve the remainders of the same form and have larger number of the valves, inhabit either the deep-sea region or the extreme north. The similar relation is also found in the two groups of the southern form. These facts may contribute much in formulating the hypothesis that the number of valves is an adaptive character probably correlated with the climatic factor. But, it is interesting to note here that a fish with a smaller or larger number of valves is occasionally found in the species thought to be either primitive or specialized as a whole.

With regard to the reason why the valves are more numerous in the northern or

deep-sea species than in the southern or shallow-water ones we have to quote the hypothesis proposed by MATSUBARA (1943, p. 158) on the variation of the pyloric coeca in Japanese scorpaenoid fishes: "The stronger or larger amount of the ferments are fundamentally necessitated in fishes inhabiting in the colder waters than in warmer waters to facilitate normal digestion. The fact that the coeca are more numerous in northern form is originated to increase such value." This may also be applicable in this case. This hypothesis may be supported by the fact that successive changes in the number of the intestinal valves seem to correlate to some extent with changes of the temperature in the sea where parent females with matured eggs were caught (Fig. 49).

Taking these into consideration, the number of the intestinal valves in Japanese rajids may be estimated as a specific character to be used to some extent in our classification of the fish.

e. Heart valves

1. Description in general

The heart valves of the elasmobranchs have been studied by some ichthyologists from viewpoints of taxonomy and phylogeny of the fish. GARMAN (1885, 1913) gave a somewhat extensive description of the organ. WHITE (1936, '37) made a much more intensive study of this organ leading to her conclusion, when she had examined a large number of species of each group of the animal taken from all the seas in the world. These works have made valuable contributions for establishing the knowledge of higher categories in the systematism of this group of fish. We are rather lacking in the knowledge of dealing with such a small group as Japanese rajids. Therefore, it is the main aim of this chapter to determine whether or not the characteristics found in the heart valves of Japanese rajids are important for the systematism of this group, and how much the results obtained from this study will agree with the past authors.

The conus arteriosus of the ventricle, which is formed by a relatively thickened muscular wall in the rajids, is furnished internally with several rows of the semilunar valves, as in other elasmobranchs (Fig. 50). In the preparation of the samples examined, the ventral border of the conus arteriosus was dissected on the mesial line,

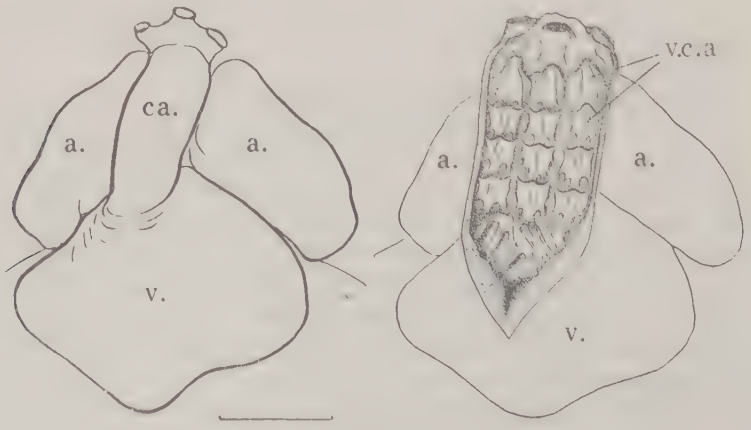

Fig. 50. Ventral aspect of the heart and its valves in the conus arteriosus of *Raja kenojei*. a., auricle; ca., conus arteriosus; v., ventricle; v. c. a., valve of conus arteriosus. Scale represents 1 cm.

and then stained with a dye, cyanine 5 R (KUSAKABE, 1953), for a few seconds. The heart valves thus arranged in both longitudinal and transverse series were clearly observed *in situ*.

The heart valve varies to some extent even in members of the same species. The variations are found in the number, location and feature of the valves. Accordingly, it must be emphasized that a considerable number of specimens of the same species should be examined so as to be useful for determining even one of the contributing characteristics in establishing a classification.

In the present study, the author has examined the features of the heart valves using a considerable number of specimens of all the Japanese rajids, and the results obtained were compared with the characteristics found in the organ of other batoid fishes in order to develop a hypothesis that would seem to correlate with differentiation of this organ throughout batoids.

2. Comparison of the heart valves

From the number and the manner of arrangement of the heart valves in the Japanese rajids dealt with, the following four groups may be assorted, abbreviated herein as Group-V^1, -V^2, -V^3 and -V^4, respectively. Group-V^1 involves fishes referable to the two species **A** and **L**. In this group (Fig. 51 **A**), the organ is in

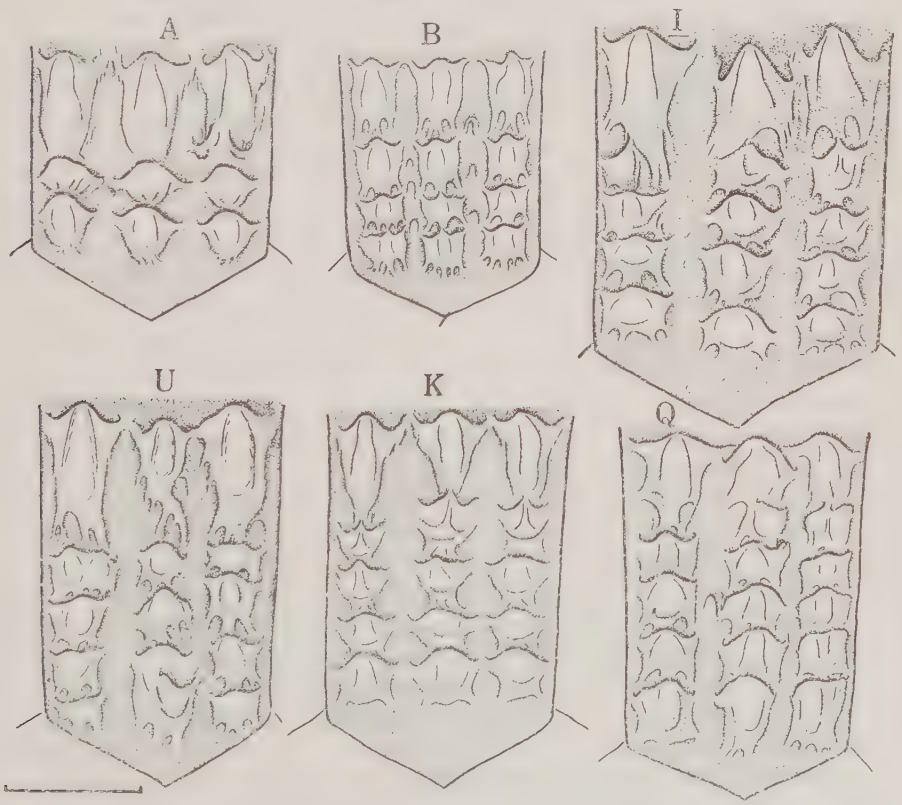

Fig. 51. Heart valves in six forms of rajids, especially showing interspecific variation in the number of valves in a longitudinal row. **A**, *Breviraja tobitukai*; **B**, *B. isotrachys*; **I**, *B. smirnovi smirnovi*; **K**, *Rhinoraja kujiensis*; **Q**, *Raja porosa meerdervoorti*; **U**, *R. pulchra*. Scale represents 1 cm.

many cases composed of three tiers of valves, but sometimes has four tiers in a longitudinal row. Group-V^2 is exemplified by the following many species which are regarded as both northern and southern forms, namely **B, C, D, E, F, H, I (I′), M, N, O, P, R, S, T, U, V** and **W** (Fig. 51 **B, I, U**). In these species, the valves are developed as four tiers in three rows in most cases. Group-V^3 may be referred to such three species represented herein as **G, J** and **K**, whose organs possess four or five tiers in three distinct rows (Fig. 51 **K**). Group-V^4 involves only one example referred to **Q(Q′)**, in which the organ is observed to have from four to five or even to six tiers in three rows (Fig. 51 **Q**).

In most of Japanese rajids, the heart valves are thus found to have four tiers of valves in three rows, and the fish may be arranged conventionally into four groups as mentioned above. The least number of tiers in the valve is found in Group-V^1, in which the species **A** has three tiers of valves in a row in most cases. On the other hand, the greatest number of tiers is represented by Group-V^4, in which the species **Q** usually has from four to five tiers and occasionally six in a row. The counts of tiers of the valves in each species of Japanese rajids may vary as shown in the following table.

Table 11. Frequency distribution in number of tiers in the longitudinal rows of the valves of conus arteriosus in Japanese rajids. Number of specimens in each species is parenthesized. **A**, *Breviraja tobitukai;* **B**, *B. isotrachys;* **C**, *B. trachouros;* **D**, *B. abasiriensis;* **E**, *B. diplotaenia;* **F**, *B. matsubarai;* **G**, *B. aleutica;* **H**, *B. parmifera;* **I, I′**, *B. smirnovi smirnovi* including *smirnovi ankasube;* **J**, *Rhinoraja odai;* **K**, *Rh. kujiensis;* **L**, *Rh. longicauda;* **M**, *Raja kenojei;* **N**, *R. acutispina;* **O**, *R. hollandi;* **P**, *R. macrophthalma;* **Q, Q′**, *R. porosa meerdervoorti* including *porosa tobae;* **R**, *R. fusca;* **S**, *R. schmidti;* **T**, *R. tengu;* **U**, *R. pulchra;* **V**, *R. macrocauda;* **W**, *R. gigas.*

Species \ Tiers		3	4	5	Species \ Tiers		3	4	5	6
A	(12)	10	2	—	M	(9)	—	7	2	—
B	(8)	—	8	—	N	(8)	—	8	—	—
C	(9)	—	9	—	O	(10)	—	7	3	—
D	(4)	—	4	—	P	(10)	—	9	1	—
E	(6)	—	6	—	Q, Q′	(13)	—	7	5	1
F	(5)	1	4	—	R	(8)	—	5	3	—
G	(5)	—	2	3	S	(9)	—	7	2	—
H	(1)	—	1	—	T	(8)	—	5	3	—
I, I′	(7)	—	7	—	U	(10)	—	8	2	—
J	(9)	—	5	4	V	(4)	—	4	—	—
K	(5)	—	2	3	W	(4)	—	4	—	—
L	(4)	3	1	—						

3. Discussion

Use of the heart valves in taxonomy

As regards the heart valves of the Japanese rajids, the present writer has focused his attention on, (i) the number of tiers in a longitudinal row, and (ii) intra- and interspecific variations of features of the valves. These characteristics, however, seem to be less important for specific definition than other anatomical features treated

from a viewpoint of taxonomy because we have found imperceptible variations between species and even between groups of species, and found many individual variations. However, the features of the organ thus far examined may be supposed to have the following traits: i) the number of distinct longitudinal rows is three without exception; ii) the number of tiers in a row ranges from three to six, and this low counts predominates in the northern form as compared with the southern form; and iii) the valves have rather well-defined features in the southern form than in the northern one.

Consequently, the features of the heart valves, so far as the Japanese rajids are concerned, may be recognized as mere characteristics in distinguishing larger groups of species in the batoids. The hypothesis may be applied to the following items.

(1) **Relation of the features of the heart valves to phyletic trends supposed from other anatomical features:-**

GARMAN (1913) conjectured that "rather generally the number of rows of valves in the conus of the Antacea decreases with advance in rank, with increase in specialization. In the Platosomeae the rule does not hold so well." This opinion has been generally accepted by DANIEL (1928). On the other hand, WHITE (1937) stated that: "In the Platosomeae, the number of tiers in each longitudinal row is rather increased, reaching six and sometimes even seven, but in some species they are very few in number. The tendency in the elasmobranchs is for duplication of valves rather than reduction, and this duplication may take place transversely as well as longitudinally." Such being the case, the conclusions of the two authorities are opposite each other especially in respect to the Antacea but they are rather in agreement in respect to the Platosomeae. It is also the case with our rajids. Namely, in the northern form, which is thought to be more primitive on the whole than the southern one, the heart valves are relatively small in the number of tiers in a row with a few exception. Further, it may be noticed here that the least number of tiers in a longitudinal row is represented by the species **A**, which is believed to have many generalized features, as mentioned elsewhere. Besides, the largest number of organs is found to exist in the subspecies **Q** and its relative **Q'**, whose characteristics are generally the most specialization in the related members.

(2) **The heart valves may be supposed to represent a mutable feature:-**

In the present item, the writer has attracted attention to the following two facts: i) The specialization of the heart valves may have occurred in the species specifically:- Although the features of the heart valves of Japanese rajids are seemingly expected to show phyletic trait in some cases, as already mentioned, the organ, on the contrary, may be assumed to have evolved species specifically. For example, in the species referred to the northern form is one having the characteristics of the organ without any phyletic relation, but of seeming importance in the species specifically. To be more exact, although the two groups of species, such as **F** and **G**, and **K** and **L** belong different phyletic stems in the northern form, they are assorted into another two groups, such as **F** and **L**, and **G** and **K**, in respect to the characteristics of the organ (cf. Table 11). A similar phenomenon is noticed in the southern form, the two groups of species **O** and **P**, and **T** and **U**, for instance, have mostly four tiers in a longitudinal row, though the two groups have no close relation to other anatomical features. It may be thought, therefore, that the features relating to the heart valves in rajid fishes must have resulted from much more complex causes than were originally supposed. ii) Variations of the heart valves in other batoid fishes:- In order to make a comparison of the characteristics of the organ between

the rajids and other batoids, the present writer has examined several representative species of the families of the batoids as shown in Table 12 and Fig. 52.

Table 12. Showing the characteristics of the heart valves in nine species of five representatives. Number of specimens examined is in parenthesis.

Family	Species		Heart valves	
			No. row	No. tiers in a row
Rhinobatidae	*Rhinobatos schlegeli*	(2)	3 — 4	4
	Rhynchobatus djiddensis	(2)	3 — 4	6
Platyrhinidae	*Platyrhina sinensis*	(2)	3	4
Dasyatidae	*Dasyatis akajei*	(2)	3	4
	Ulorophus aurantiacus	(2)	3	4
	Gymnura japonica	(2)	3	5
Myliobatidae	*Holorhinus tobijei*	(2)	3 — 4	5
Torpedinidae	*Narke japonica*	(2)	3	2

It may be seen from these table and figure that the characteristic in question varies a little as a rule even in different families, except for the Torpedinidae. In *Rhinobatos* (1, 2 in Fig. 52), there are four tiers set in three or four longitudinal rows with small accessory valves. But, there are six tiers set in three distinct longitudinal rows with incomplete valves forming a row, in other species of the same

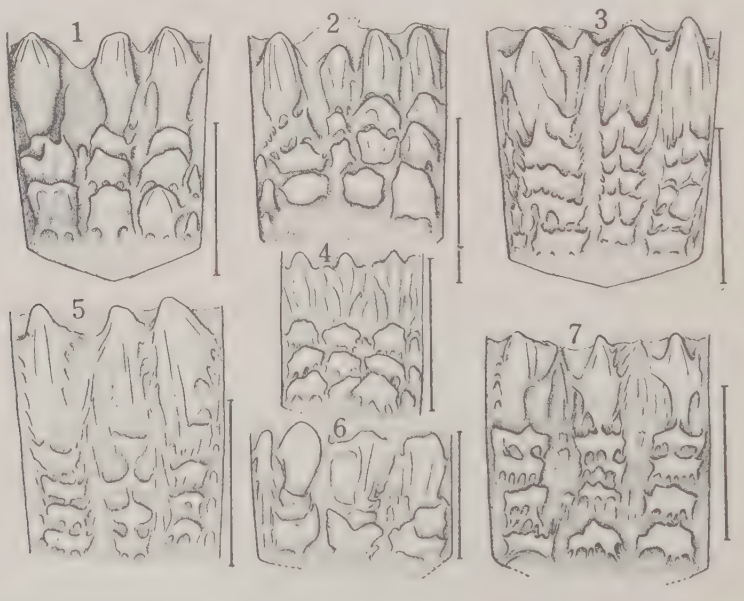

Fig. 52. Heart valves in six representatives in batoid fishes, especially showing intra- and interspecific variations in number and arrangement of the valves. 1 and 2, *Rhinobotos schlegeli;* 3, *Rhynchobatus djiddensis;* 4, *Platyrhina sinensis;* 5, *Gymnura japonica;* 6, *Narke japonica;* 7, *Holorhinus tobijei.* Scales denote 1 cm other than 6 with 5 mm.

family, *Rhynchobatus* (3 in Fig. 52). Further, in both *Gymnura japonica* and *Holorhinus tobijei*, the heart valves are found to have five tiers of three longitudinal rows though these two representatives are thought to have diverged greatly in their phyletic relation (5, 7 in Fig. 52). Moreover, there exist in *Platyrhina sinensis* (4 in Fig. 52) four tiers of three longitudinal rows with undifferentiated valves in a row, and there are very irregular valves with two or three tiers of three or four longitudinal rows in *Narke japonica* (6 in Fig. 52).

To summarize the above, the author has come to the conclusion that the feature of the heart valves may be no more than a variable characteristic which is merely of specific importance in some species and in some particular group of the batoids as its diagnostic sometimes. As the two cases mentioned are well relevant to our rajids, the writer has inferred that the variation is doubtless an indication of mutating feature without any relationship suggestive of a tendency associated with genealogical trends.

f. Placoid scales and its derivatives

1. Description in general

Some information on the placoid scales of the elasmobranchs has been given by many authorities, and the features in the scales have been regarded as most important characters in the taxonomy of the fish. In fact, many elasmobranchs have their skin covered with placoid scales or its derivatives to some extent, varying from group to group. In the Rajidae, the body is usually covered with scales on both surfaces more or less regularly, but the dorsal side is more setose with small or spine-like denticles than the ventral, where a small area is furnished with minute scales or is smooth, in most cases.

To the best of the present writer's knowledge, the feature or genetic regularity in the scales of rajid fishes has not been treated of in the taxonomy to a comprehensive system. The main aim of the present scheme is, on one hand, to give some noteworthy knowledge of identifying species or group of species, and, on the other, to arrange those characteristics found in the scales in a compact system.

2. Comparison of placoid scales

1). Features and tracts of placoid scales in Japanese rajids:

A thorough examination and comparison of the scales of all the species dealt with in this study including many specimens ranging from the adult to very young fish has shown that there is a remarkable difference in both features and tracts of scales between the northern and southern forms. Usually, the scale has a broad base and sharply pointed process in the northern form, whereas in the southern one the scale mostly has a spiny process with no broad base.

As regards the tract of scales, it is much diversified between the two forms. In the northern members, the entire dorsal surface of the body is usually crowded with scales, visibly so in the tail, which is conspicuous in the young fish, but in the southern members scales are sparsely present on the body, on the whole, retaining some definite tracts and leaving a large smooth area in the disc.

It some species of rajid fishes, some of the scales on the dorsum develop into large spines with more or less regularity, and the characteristics in number and in arrangement of the enlarged scales are among the most important marks of a species or groups of species. Generally, large spines are developed on the nuchal and shoulder regions, on upper margins of the orbits, and on mid-dorsal line running

backward from the nuchal to the dorsal fins. Besides, a pattern of backlar spines, the so-called alar spines, never fail to occur on the marginal portion of each pectoral fin of the matured male. Of these, the spines developed on orbit, shoulder region and mid-dorsal line are more or less different in the mode of development between the two major forms of Japanese rajids. These differences in the features and tracts of the scales between the two forms are mentioned in detail with the following scheme.

2). **Mode of genesis of the scale in both ontogenic and genealogical series:**

As already annotated above in the northern form, the scales are developed on the whole dorsal side of the body in the young or at least on the tail in the adult, whereas in the southern form the denticles mostly occur in much less degree even in the adult. Although these diversities in the spination are found to exist between the two aforementioned, there are many phases in the degree of development, varying from species to species or with the growth of the body even in a single species in the respective form. Thus, on the basis of the characteristics in spination outlined, Japanese rajids may be divided into two types and called herein Types Sc^N and Sc^S, which are referred respectively to the northern and southern forms.

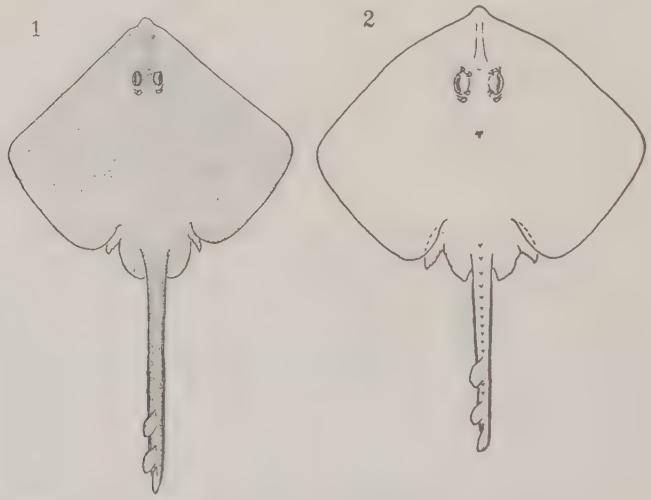

Fig. 53. Showing two types of the spinations in the young of Japanese rajids. 1, northern form; 2, southern form.

Type Sc^N is characterized by having the scale with a broad, stellate base and sharply pointed process, and in the fishes of this type the dorsal surface is entirely covered with denticles at least in the young and the tail, in the adult. The spination of the disc including the pelvic fin, however, becomes either sparse or setose in the adult in some degree, and the degree of spination is more or less different in species or between the sexes. Further, this type may be subdivided into six subtypes, Sc^{NA} to Sc^{NF}, mainly based upon the degree of development of the prickles, the number and the mode of arrangement of enlarged spines or thorns found in the adult.

Subtype Sc^{NA} is modeled after the characteristics in the spination found in the species A(Fig. 60 A_1); the spination on the whole dorsal surface of the body is always uniformly and densely covered with numerous prickles without enlarged spines, and no differences are found in spination regardless of the age and the sex even in the adult,

excepting the alar spines*). Subtype Sc^{NB} is exemplified by the two species **B** and **C** (Figs. 61, 62; B_1 and C_1); the dorsal surface of the disc is also covered with numerous pricklly scales even in the adult stage, but this subtype is distinguished from the preceding in most cases by having a row of nuchal and tail spines and one shoulder spine. Some differences in the mode of development of the prickles and the spines are found to exist between the two species referred to this subtype; the prickles covering dorsal surface of the body in the species **B** are denser and smaller in size than those in the species **C**, and enlarged spines developed on nuchal and shoulder regions are usually well marked in the species **B**, though they are obscure in the species **C**. These differences in the spination between the two species are more distinct in their adult stage than in their young stage.

Subtype Sc^{NC} involves the two species **J** and **L** (Figs. 70, 71; J_1 and L_1); the spination characterizing this subtype is the presence of a row of large spines running along mesial line of the tail together with numerous prickles covering dorsal surface of the body even in the adult. When the species **J** is compared with the species **L** in spination, the former is distinguished from the latter by having mid-dorsal belt of somewhat enlarged prickles developed on the disc, though the latter has no such pattern of enlarged scales, but has a row of nuchal spines, which the former has not.

Subtype Sc^{ND} may be referred to the spination revealed by the three species **D**, **E** and **F** (Figs. 63, 64; D_1, E_1 and F_1); the spination characteristic of this subtype is noticed by remarkable reduction in the disc of the adult, leaving the mid-belt and marginal pattern of the prickles, and by a row of enlarged spines set on the tail. But the three species are different from one another in spinations as follows: the nuchal and shoulder spines are absent in the two species **D** and **E**, while they are present in the species **F**, and in the species **E** and **F** the tail spines are usually well developed set regularly in a row, but in the species **D** they are obscure, occurring at places. The degree of reduction in the spination revealed in the dorsal surface of the body with the growth of the fish appears greater in order of **D**, **E** and **F**.

Subtype Sc^{NE} involves the three species **G**, **H** and **K** (Figs. 66, 67, 72; G_1, H_1 and K_1); the spination in this subtype is rather distinguished from those in the relatives by having a row of large spines running continuously from the center of disc to the dorsal fins, and by having one or two spines on each shoulder. By those patterns of the prickles and enlarged spines developed on the dorsal surface of the disc and on the tail, the three species can be distinguished from one another as follows: dorsal surface of the disc is more or less densely covered with numerous prickles in the adult of the species **G** and **K**, though it is smooth in its main portion in the species **H**, and the prickles of the species **K** are larger in size than those of the species **G**, but in the species **H** they are much more distinctively developed with a broad stellate base on the head; number of the large spines set on the shoulder is measured as two in the species **H** and **K**, but mostly one in the species **G**.

Subtype Sc^{NF} is modeled after the characteristics in the spination of the two subspecies **I** and **I′** (Figs. 68, 69; I_1 and I'_1); the mode of spination in these examples appears similar to that of the species **H**, but the members of this subtype are discriminated from the latter; dorsal surface of the disc becomes almost smooth in the adult and subadult stages of this subtype, except for those prickles developed on the anterior marginal portion of the disc, the frontal and interorbital spaces of the eyes and on the

* The occurrence of the pattern of the enlarged thorns is so generalized in the matured male of Japanese rajids that the thorns are excluded from the characteristics of this subtype, and so on.

basal portion of the tail. A group of two or four nuchal spines and a shoulder spine are also present in this subtype. A remarkable fact in this subtype is the occurrence of minute prickles on the dorsal lobe of the glans clasper, as mentioned elsewhere (cf. **I** and **I'** in Fig. 3).

Type Sc^{S} is referred to the features of spination in the southern form; the scale is usually developed in spiny or enlarged prickle with no broad stellate base, and in young stage the spines developed with definite positions on dorsal surface with common tracts are much fewer than in the adult stage except the species **W**, and the body becomes more setose with age, giving specific and sexual differences. On the basis of these characteristics, this type may be classed into six subtypes, Sc^{SA} to Sc^{SF}.

Subtype Sc^{SA} involves those three species represented by **M**, **T** and **V** (Figs. 36 and 37; **M, T, V**); the spination characteristic in this subtype is revealed principally by the mode of development of the spines on the tail, i. e. a row of spines in the male and three rows of the same in the female run along the upper surface of the tail, and one nuchal spine mostly occurs in the center of the disc. Comparing the three species of this subtype in the degree of development, the manner of arrangement of the spines and prickles developed on the tail and the disc, the author has found some differences and discriminated them one another, viz., in the species **M** and **T** the spines running in irregular series along the mesial line of tail are numerous and well-developed (Figs. 36 **M** and 37 **T**), though they are rather few and weak in the species **V** (Fig. 37 **V**), and the nuchal spines in the adult of the species **M** are more numerous, varying from one to four in number in most cases, but in the other two species the spines occur usually as one, and the ventral side of the head is thickly furnished with minute prickles in the adult of the species **T**, though in the species **M** and **V** the distal portion of snout is only setose.

Subtype Sc^{SB} is represented by only one species **U** (**U** in Figs. 30 and 37); the spination in this subtype is rather similar to the preceding case, especially so in the male, but the female is distinguished from the relatives by having five rows of spines on the dorsal surface of the tail when matured. The manner of development of prickles and spines developed on dorsal border of the disc appears to resemble especially that of the species **T**.

Subtype Sc^{SC} involves but one species **W** (Fig. 86 **W**); the spination is singular in both young and adult stages, i. e. minute prickles are entirely but sparsely developed on the disc and the tail in the young in addition to the common tracts of large spines characteristic of the young of the southern form (**W** in Fig. 84), but the minute prickles disappear when the fish get into the adolescent stage. Further, the row of large spines set on the tail of the adult male is worn away in most cases or is reduced to a vestige in some occasions, but the spines in the adult female become thicker, set in three distinct rows (Fig. 37 **W**). Dorsal surface of the disc in the adult of both sexes is provided with rather similar tract of the prickles and spines, as in the case of the species **T** and **V**, but the present species bears numerous prickles on the snout and interorbital space.

Subtype Sc^{SD} is modeled after the spination revealed in the adult of species **R** (Fig. 36 **R**); the degree of development of the armature on the tail and nuchal regions is rather the same between the two sexes, having three rows of the tail spines and three to five nuchal ones, whereas anterior margin of the disc is more setose in the male than in the female, as is usual in this form. Ventral surface of the body is devoid of the spination except the distal portion of the snout.

Subtype Sc^{SE} is exemplified by the two species **N** and **S** (Figs. 36 and 37; **N**,

S); the spination characteristic in this subtype is marked in the following respects; the spines on tail are set in three rows in the male, but in many irregular rows in the female which are numerous, irregularly covering the tail. Tail spines in a row are fewer in the species S than in the species N, but the reverse is the case with the orbital spines.

Subtype Sc^{SF} is referred to the manner of spination revealed by the three species, O, P and Q (Q′) (Figs. 75—79); the features of the spination of the adult male are rather similar to those found in the preceding subtype, in having three distinct rows of tail spines, but the present subtype can be distinguished from the preceding one in having five rows of spines arranged regularly on the tail of the adult female, in usual cases. The number of nuchal spines decreases in order Q (Q′), P and O, measuring respectively from 3 to 6, from 2 to 3 and from 1 to 2, in most cases, whereas the tail spines become thicker in order O, Q (Q′) and P (Fig. 36). The nuchal spines of species P is developed in a triangular position in many cases.

3. Discussion

1). Systematic significance of the scales in Japanese rajids

Although the features of the scales may provide us with some informal ways of finding a clever method of separating species or group of species in rajids, the characters vary so much even within a single species that it is not an easy task to obtain a compact knowledge responsible for a practical index in distinguishing any species including younger and older specimens. But on the basis of the characters mentioned in the foregoing section, the present writer has given the following key that may be useful for the heading of the present section.

1a. Type Sc^{N}: Entire dorsal surface of the body more or less thorny with numerous prickles bearing stellate broad bases in the young stage without exception, but the spination of the disc in the adult is either as thick or fewer than that of the young, and the dorsum of tail is always wholly furnished with numerous scales even in the adult; sexual difference in the spination of the disc more or less obscure except the alar spines.

2a. Subtype Sc^{NA}: Dorsum of body entirely setose even in the adult stage; regardless of age and sex, present in spination without enlarged spines set on nuchal, shoulder and tail regions..... *Breviraja tobitukai* (A in Figs. 30 and 60)

2b. Dorsum of the disc more or less setose in the adult stage, having either numerous prickles or smooth portion, but the tail is always covered with prickles with a row of enlarged spines.

3a. Dorsum of the disc entirely setose even in the adult; a number of large spines set either on nuchal or shoulder region, or on both regions present or absent, the spine on nuchal, if present, is interrupted from that of the tail.

4a. Subtype Sc^{NB}: Both nuchal and shoulder spines present.

5a. Prickles covering dorsal surface of the body very thick, but minute; both nuchal and shoulder spines apparent in most cases .... *B. isotrachys* (B in Figs. 35 and 61)

5b. Prickles covering dorsal surface of the body rather sparse and large in size; both nuchal and shoulder spines somewhat obscure in many cases .... *B. trachouros* (C in Figs. 35 and 62)

4b. Subtype Sc^{NC}: Shoulder spine absent; if nuchal spines present, dorsum of disc is provided with prickles without noticeable pattern of modified scales.

6a. Nuchal spines absent, but with a mid-belt of somewhat enlarged prickles

running from nuchal to basal portion of tail .....
..... *Rhinoraja odai* (J in Figs. 35 and 70)

6b. One to four, mostly three, nuchal spines present; basal portion of the pectoral fin somewhat sparse in matured male .....
..... *Rh. longicauda* (L in Figs. 35 and 71)

3b. Dorsum of the disc partly setose in the adult due to reduction of the spination; nuchal and shoulder spine, or either present or absent, the nuchal one, if present, interrupted from that of tail.

7a. Subtype Sc^{ND}: Shoulder spine absent; if nuchal spine present, main portion of the dorsum of disc entirely naked when matured.

8a. Nuchal spine absent; basal portion of the pectoral fins more or less smooth when matured.

9a. Enlarged spines of the tail obscure, set at places; basal portion of the pectoral fin and posterior end of the pelvic fin sparsely thorny even in the adult stage, leaving a broad mid-belt of the prickles .....
..... *B. abasiriensis* (D in Figs. 35 and 63)

9b. Enalrged spines of the tail distinct, set in a regular row; basal portion of the pectoral fin as well as the pelvic fin almost smooth, leaving a mid-belt of the prickles ..... *B. diplotaenia* (E in Figs. 35 and 64)

8b. Two to four nuchal spines present; dorsum of the disc entirely smooth except anterior marginal portion, mid-belt and snout, which are sparsely armed in the adult ..... *B. matsubarai* (F in Figs. 35 and 65)

7b. Both nuchal and shoulder spines present; dorsum of the disc wholly smooth or setose in the adult, if setose, row of nuchal spines is connected with that of tail, reaching to the dorsal fin.

10a. Subtype Sc^{NE}: A row of large spines presnt, running continuously rearward of nuchal region to dorsal fin; clasper devoid of prickles.

11a. Dorsum of the body thorny even in the adult, bearing numerous prickles, but basal parts of the pectoral fins are sparser in the adult.

12a. Prickles of the body somewhat thickened; a pair of large spines present on each shoulder; ventral side of the head smooth, excepting distal portion of the snout; a row of large spines set along mesial line of the disc always distinct ..... *Rh. kujiensis* (K in Figs. 35 and 72)

12b. Prickles on the body very small; one shoulder spine present on each side; ventral side of the head thorny; a row of large spines set along mesial line of the disc obscure, in some cases, reduced on its halfway point ..... *B. aleutica* (G in Figs. 35 and 66)

11b. Dorsum of the body wholly naked on its main portion except for anterior marginal portion of the disc and inner margins of the orbit, where the prickles with broad stellate bases are sparsely developed .....
..... *B. parmifera* (H in Figs. 35 and 67)

10b. Type Sc^{NF}: Two to four, usually 4, nuchal spines present; dorsum of disc wholly smooth except those portions with prickles marked in the preceding species; dorsal lobe of the glans clasper developed few minute prickles..... *B. smirnovi smirnovi* (I in Figs. 35 and 68); *B. smirnovi ankasube* (I′ in Fig. 69)

1b. Type Sc^{S}: Dorsal surface of body in the young entirely smooth with the exception of large spines set on definite positions, except the species W, but the spination becomes more thorny with the growth of body, giving remarkable sexual difference

to the character especially of the tail, in most cases.

13a. A row of large spines present on dorsal mid-line of tail in adult male, but three or five rows in adult female; only one nuchal spine present in most cases.

14a. Subtype Sc^{SA}: Three regular rows of spines present on the tail in female.

15a. Spines on tail sharp and thickened, developed in numerous number when matured.

16a. Nuchal spines two to four; ventral surface of head smooth except tip of the snout in adult fish .... *Raja kenojei* (**M** in Figs. 36 and 73)

16b. Nuchal spines one to two in most cases; ventral surface of head thorny by having minute prickles when matured .... *R. tengu* (**T** in Figs. 37, 82 and 84)

15b. Spines on tail rather few and reduced in size: nuchal spine mostly one or two: ventral side of head almost smooth except tip of snout .....*R. macrocauda* (**V** in Figs. 37, 84 and 85)

14b. Five or three rows of spines distinctly developed on the tail in matured female.

17a. Subtype Sc^{SB}: Spines on tail rather small in both sexes, but numerous in the adult, bearing five rows in female; spination in the young developed with common tract in the southern form ..... *R. pulchra* (**U** in Figs. 30, 37, 83 and 84)

17b. Subtype Sc^{SC}: Spines on tail usually reduced, worn out in adult male, but they remarkably thickened and set in three rows in adult female; numerous prickles present on dorsum of body in the young, but they almost disappear with growth of the fish.....*R. gigas* (**W** in Figs. 36, 84 and 86)

13b. In adult, three rows of spines present on tail in male, but three or five rows in female; nuchal spines usually numerous.

18a. Subtype Sc^{SD}: Three rows of spines present on tail in both sexes; nuchal spines three or five followed by numerous somewhat enlarged scales in female ....*R. fusca* (**R** in Figs. 36 and 80)

18b. Five or irregular rows of spines developed on tail in matured female, but three rows in male.

19a. Subtype Sc^{SE}: Numerous spines in irregular rows thickly covering tail in female.

20a. Tail spines very few in adult male, but orbital ones more numerous than in that of 20b. .... *R. schmidti* (**S** in Figs. 37 and 81)

20b. Tail spines developed in three distinct rows, but orbital ones about five to six developed on each side ..... *R. acutispina* (**N** in Figs. 36 and 77)

19b. Subtype Sc^{SF}: Five rows of spines set regularly on tail in matured female..... *Raja porosa meerdervoorti* (**Q** in Figs. 36, 77 and 78); *R. porosa tobae* (**Q′** in Figs. 36, 78 and 79); *R. hollandi* (**O** in Figs. 36 and 75); *R. macrophthalma* (**P** in Figs. 36 and 76)

2). Relation between the degree of development of the spination and the geographical distribution of Japanese rajids

It is generally known in fish and in other animals that the features of scales tend to vary from species to species with their geographical distributions. Such geographical variations of a character as occur in close relation with niches of the fish in a group must not be overlooked and must be considered important for distinguishing species, and it should also be noticed whether or not the feature is useful for assuming genealogical pedigree in the group of animals.

In the Rajidae, scale features differ very much between the northern and the southern forms, as mentioned in the foregoing section. These differences in the feature are opposed not only in the ontogenic development of the fish, but also in the genealogical trend between the two series of Japanese rajids. In the northern members, there is a tendency that the more northward or the deeper the sea is where a species lives, the greater degree of diminution in the number or the less degree of specialization in the feature of scales takes place. For example, the species **A**, which is referred to subtype Sc^{NA}, is found to inhabit southernmost area of the region where the northern members are distributed, and the species **B**, **C**, **J** and **L**, which are characterized by having the spination of the subtypes belonging to either Sc^{NB} or Sc^{NC}, are found only to inhabit more northerly regions than the preceding species. Subtype Sc^{ND} of the spination is represented by fishes which range still farther northward or in deeper waters with gradual changes of degree of diminution of the scales developed on the disc. Thus, we can generally confirm the opinion given above.

In the southern form, the transpecific variations of the character in relation to geographical distribution show rather a similar tendency to that of the northern form mentioned above, though the change of spination during ontogenic development is quite antagonical between the two forms as afore-explained. Namely, the degree of development of the spination becomes greater with changes of the habitat either direction from north to south or from deep waters to shallow ones. For example, the three species, **M**, **T** and **V**, which are referred to subtype Sc^{SA}, inhabit the region ranging from moderate to deeper waters in parallel with change of the degree of development of spination in their adult stage. Further, the species **N**, **O**, **P**, **Q** and **R** are more setose than those preceding ones, and are dwellers in the shallower waters or in the south of an area distributed by the southern members. Thus, we may recognize many cases which agree with the hypothesis mentioned above concerning the degree of development of the spination and geographic distribution of the fish, though some cases are found contradictory to this phenomenon.

As regards the reason why such geographical variation in the features of spination takes place in some degree of correlation, the present writer has ventured the following phypothesis in order to interpret the question concerning a suggestion given by WHITE (1937, p. 62), that "the history of denticle in general shows that their development is more directly affected by the environment than is that of other external characters. There is definite similarity ....., and while it is impossible to test the condition of the environment in all cases, it is probable that temperature, depth and exposure are all concerned." Indeed, these factors may affect directly or indirectly the differentiation of the denticles of rajid fishes, but the writer should like to add a biological factor to these physical ones. Discussions shall be given below.

3). Relation between the degree of development of the spination and that of the electric organ of the tail

It is worth finding that the degree of development of the scales of the tail to some extent seems related to that of the electric organ, and besides, the two organs reveal a remarkable sexual difference in the southern members in most cases, but the difference is very slight or absent in the northern members.

Usually, sexual dimorphism in the spination is developed in some degree in several portions of the body of rajids. In the matured fish, a patch of backlar spines, such as alar and malar ones, is distinctively developed only in the male, but the spination is greater in the female than in the male in most cases, and this tendency is remarkable especially in the tail of the southern form.

It was formerly suggested by the present writer that the scales are developed in order to protect the body, and that the electric organ may serve for a similar biological function or may be used as the sex-relating apparatus. In other words, the two organs seem to have a single but complex biological significance in the tail of rajids.

As already mentioned elsewhere, the degree of development of the electric organ is positively correlated with that of reduction of the length of the tail, but the degree of development of the spination appears to affect the length of the tail in less degree.

In the northern members, for instance, the successive change of relative length of the tail is supposed to occur in direct proportion only to the degree of development of the electric organ, and regardless of sex, the fishes are all dressed in numerous scales on the tail with slight difference in the spination among species.

In the southern members, on the contrary, the successive change of the length of the tail seems to be associated not only with that of the electric organ, but also with that of the spines on the tail. In fact, both electric organ and spination are better developed in the female than in the male, the former having a longer tail in most cases. If both organs are almost the same in their degree of development between the sexes, as in the case of the species **R**, the length of tail is not so different between the sexes (cf. **R** in Fig. 32), as is the case with the northern form, where the two organs are developed in the same degree between the sexes partaining to the same length of tail (cf. Fig. 36 **R**). Further, the electric organ becomes enormously large in size, as is observed in the species **V** and **W** (cf. Fig. 37 **V**, **W**), whose spinations of the tails are reduced or eventually lost, accompanying remarkable sexual differences in the length of tail. This fact makes us infer that the less the spines on the tail are developed, the more the electric organ is developed. The development of the electric organ positively affects the reduction of the tail, as already explained elsewhere. In another instance, however, the degree of development of the spination of tail appears negatively correlated with that of the electric organ, as in the case of the species **N**, **O**, **P** and **S** of the southern form, and **A**, **J**, **L** and **K** of the northern form. In these examples, the spination and the length of the tail are remarkable, though the electric organ is developed in less degree. These evidences mentioned above may give us a conception that relative length of the tail in the rajids dealt with here seems to have causal relation to the degree of development of either spination or electric organ, or of both, through very complex biological functions of the two related organs.

4). Consideration on differentiation of the features of spination in Japanese rajids

As already mentioned in the foregoing paragraphs, the feature of the scale varies

much not only with genealogical pedigree, but also with ontogenic series of rajid fishes, giving remarkable specific and sexual differences of the character. On the basis of characteristic features of the scale, the present writer has classed Japanese rajids in two main types, which contain six subtypes, respectively (Table 13).

Table 13. Characters of the spination of Japanese rajids, classified in two major types with subtypes respectively. For abbreviations, see text.

Type	Subtype	Characters					Species and subspecies
		dorsum of disc		nuchal spine	shoulder spine	spines on tail of adult fish; sexual difference	
		young	adult				
Sc^N	Sc^{NA}	setose	setose	absent	absent	absent	A
	Sc^{NB}	setose	setose	present	present	present; without sexual difference	B ; C
	Sc^{NC}	setose	setose	absent or present	absent	present; without sexual difference	J ; L
	Sc^{ND}	setose	setose or smooth	absent or present	absent	present; without sexual difference	D ; E ; F
	Sc^{NE}	setose	setose or smooth	present	present	present, continuous with nuchal; without sexual difference	G ; H ; K
	Sc^{NF}	setose	smooth	present	present	present; without sexual difference	I ; I′
Sc^S	Sc^{SA}	smooth	smooth	present	absent	present; with sexual difference, one row in male, three rows in female	M ; T ; V
	Sc^{SB}	smooth	smooth	present	absent	present, with sexual difference; one row in male, five rows in female	U
	Sc^{SC}	setose	smooth	present	absent	present; with sexual difference; one row or absent in male, three rows in female	W
	Sc^{SD}	smooth	smooth	present	absent	present; without distinct sexual difference, three rows in both sexes	R
	Sc^{SE}	smooth	smooth	present	absent	present; with sexual difference, three rows in male, irregular numerous rows in female	N ; S
	Sc^{SF}	smooth	smooth	present	absent	present; with sexual difference, three rows in male, five regular rows in female	O ; P ; Q ; Q′

Of the features of scale given in the preceding sections, the characteristics considered to be important for phyletic relationships of the organ of Japanese rajids are, i) general shape of the scale, ii) degree of development of the scales in the adult stage, and iii) trend of the change of spination revealed in ontogenic series of the fish. With regards to these hypothetical bases, the author has drawn his attention to the following viewpoints, so as to arrive at the conclusion of the present subject.

(i). It has generally been known that the placoid scale and its derivatives are originated from a hard armour of four layers of tissue covering the surface of body of the earliest vertebrate, from which an ancestor of the modern elasmobranchs has been derived. In fact, many of the elasmobranchs are clad in armour of placoid scales to some extent, and the condition is generally well modified in the modern batoid fish. In the Rajidae, the scale usually has spiny type which is, according to WHITE(1937), modified from the plate-like one, and the degree of reduction in thickness of the scales parallels in the main with specialization of the fish.

Observing a similar tendency in our rajid fishes, we have found that the more numerous denticles of a flattened form a species has, the more generalized condition it is in. If this hypothesis is justifiable, we may infer that the feature characteristic in the scales of the northern form, Type Sc^N, may be considered to be in more primitive condition than that of the southern one, so far as the shape of the scale and general feature of the spination are concerned.

(ii). As regards the successive change in the number of large spines developed on the body of the northern form, the present writer has considered it in the same manner as given in the above mentioned hypothesis. It is naturally believed that the enlarged spines or thorns developed with definite tracts on body surface are modified from the minute prickles so as to protect the body or to allow the fish to survive. This modification of the scales into large spines occurs along dorsal-mid line of the tail with few exceptions, and on nuchal and shoulder regions in some species. The absence of prickles, on the other hand, is mainly seen in the disc inclusive of the pelvic fins, except marginal and mesial portion of the disc, and snout and interorbital portions. The relation between the degree of development of the enlarged spines and that of reduction of prickles is considered to be very complex. However, we can reasonably assume that the species with more numerous scales without any noticeable large spines even in the adult stage seem to maintain more generalized condition than those with fewer scales with many enlarged thorns. Such being the case, the species **A** referred to subtype Sc^{NA} may be interpreted to be most primitive in spination, followed by either subtype Sc^{NB} or Sc^{NC}. It may be said, therefore, that these two subtypes may be diverged offshoots from the common ancestor similar to the preceding subtype. Subtype Sc^{ND}, which is represented by the three species **D**, **E** and **F**, may be linked with subtype Sc^{NB}, though these representatives are pretty well reduced in the number of scales. Although those three species (**F**, **H** and **K**) having a row of large spines set continuousely along the mesial line of disc are referred to the subtype Sc^{NE}, the category of the feature seems to involve somewhat conventional measure, because there is some variation in the feature of the spination among the three species. However, the present writer is inclined to proposed here the following idea that may be justifiable in this case. The outward resemblance in the feature of spination revealed by the three species of this subtype may be caused by either convergence or divergence of the character of different stock. Namely, the three representatives referred to this subtype belong to from each other different phyletic stem. At any rate, subtype Sc^{NF}, which involves the subspecies **I** and **I′**, is considered to be the most specialized phase characterized by having very few scales on the dorsum of disc and the prickles on the dorsal lobe of glans clasper.

(iii). As to the successive development of the scales in the ontogeny of the fish referred to the southern form, Type Sc^S, the hypothesis which has been adopted in the northern form is not justifiable but another one must be derived. On the theory of evolution in animals a character can be lost again in a phyletic line, and a similar or equivalent character can be required (Mayr et al., 1953). In favour of this theory, the present writer believes that Type Sc^S must have arisen from an ancestor which has almost lost the character of scales similar to Type Sc^N, and the equivalent character may have been developed in Type Sc^S with the advance of specialization of the fish. If this view be true, the successive development of scales with the growth of the body in the southern form may be considered to be equivalent but analogous to the successive reduction of the spination in the northern form. Based on this theory, Type Sc^S may be considered to be in a more advanced condition than Type Sc^N.

According to the writer's idea, it may generally be accepted in the southern members, therefore, that the more numerous scales a species has in the adult stage, the greater degree of differentiation in the spination occurs. Regarding the differentiation of the spination in this type, however, the writer believes that polyphyletic development has taken place, and the divergent or convergent variation of the character is further exhibited by the existence of remarkable sexual difference. At any rate, the subtype Sc^{SA}, which is represented by the three species **M**, **T** and **V**, is probably nearer to the original form than any other, because very few large spines are found on the tail with much smaller degree of sexual difference. Of the three, the species **T** may be accounted for as an intermediate between the two other species in respect to the degree of development of the spination. Is it not far-fetched to say that the characteristics in the spination developed in those referred to all the subtypes in the southern form except subtype Sc^{SA} may have evolved from something like the three species **M**, **T** and **V**, developing in three different directions ? From this viewpoint we may reach the conclusion that subtypes Sc^{SB} and Sc^{SC} seem to be offshoots from subtype Sc^{SA}, diverged into different form. To be more exact, the subtype Sc^{SB} may have directly sprung from a form which has a character similar to that found in the spination of the species **T**, but subtype Sc^{SC} may have diverged from the species **T** through the species **V**. We have to introduce herein again the statement made by MAYR et al. (l. c.) that the numerous prickles found in the young of the species **W** may have recovered the old character which has disappeared in the young of all species in the southern form (cf. **W** in Fig. 84). On the other hand, the species referred to subtypes Sc^{SD} or to Sc^{SF} may have been specialized from a species bearing the spination similar to that of the species **M**, by gradual increase of the scales in both sexes. Such being the case, is it not very logical to interpret that the degree of development of the spination revealed in the species **R** referred to subtype Sc^{SD} may be regarded as having the most intimate relation to that revealed in the species **M**, because three rows of large spines are developed on the tail of both sexes?

We generally agree in considering that the placoid scales are originally developed everywhere on the surface of the body without any regular arrangement. In comparison of the manners of arrangement of the spines developed on the tail of the species involved in the subtypes Sc^{SE} and Sc^{SF}, we may safely believe that the subtype Sc^{SF} seems to possess more specialized phase than Sc^{SE}, because the females of Sc^{SF} have their tail furnished with five rows of spines in regular arrangement, when the females of Sc^{SE}, with numerous rows of spines irregularly arranged. If the writer is right in presuming the differentiation of the spination, subtypes Sc^{SA} and Sc^{SF} are considered to be the two extremes in the phyletic lineage of the spination revealed in the southern form.

When we accept the foregoing conception on the courses of differentiation of the spination thus supposed, we may say that the trend in phyletic relationship especially of the southern form in Japanese rajids is generally parallel with that which has been inferred from the fact found in the clasper, but in the northern form the two trends are in discord with each other to some extent, as is the case with other adaptive characters, such as the snout and the egg-capsule.

Remarks: In many works on taxonomy of elasmobranchs, both feature and number of teeth are among the noteworthy characters. In fact, the characteristics of teeth on both jaws are frequently very different even in a group of the fish. In the Rajidae, the features which have heretofore been used in taxonomy are the number of rows and the manner of arrangement of the teeth on both jaws.

In the present study, where many specimens of all the species of Japanese rajids have been examined, the two characters of the teeth are taken into due consideration.

The principal results thus obtained in this investigation may be summarized as follows:

i). The number of teeth in rajids undergoes remarkable intra- and interspecific variations, and the method which has been customarily used may be inaccurate to some extent, because the teeth of an embryo set originally in pavement arrangement change in some degree with the development of the organ giving distinct sexual dimorphism of the teeth.

ii). From the above reason, the present writer has been able to obtain the following result: (i) the teeth on both jaws are generally more numerous in the southern members than in the northern ones, being measured 35.1-50.0 and 22.5-44.0 on the average, respectively, (ii) the difference between the species in the two major groups of Japanese rajids may not show any noticeable specific character (Table 14), and (iii) the teeth are arranged in pavement style in young fish, but in quincuncial way in the adult, being very sharp or prehensile in form in the male, though the teeth of the female are less pointed.

Table 14. Counts of teeth on the upper jaw of Japanese rajid fishes, especially showing smaller counts in the northern members (A—L) as compared with those in the southern ones (M—W). Number of specimens of both sexes examined are parenthesized. For other abbreviations, see text.

Species (♂ : ♀)	Number of teeth				Species (♂ : ♀)	Number of teeth			
	male		female			male		female	
	range	average	range	average		range	average	range	average
A (8 : 8)	41—45	43.6	38—50	44.0	M (40 : 48)	27—40	35.5	32—40	35.9
B (12 : 15)	24—28	26.5	25—31	27.0	N (31 : 29)	42—50	45.5	41—55	46.1
C (7 : 7)	21—27	24.4	20—27	24.1	O (34 : 20)	39—50	43.4	40—48	46.3
D (6 : 5)	20—27	23.8	26—27	26.0	P (13 : 14)	33—45	39.1	36—46	40.2
E (15 : 15)	26—35	29.8	29—35	31.7	Q (6 : 7)	42—54	46.4	41—51	44.6
F (5 : 5)	21—25	24.2	20—25	22.6	Q′ (9 : 13)	41—51	46.0	37—51	44.7
G (5 : 5)	33—35	34.4	30—36	32.6	R (15 : 26)	48—52	50.0	37—54	47.5
H (1 : 0)	29	—	—	—	S (8 : 16)	42—46	43.2	39—47	44.0
I (9 : 12)	22—26	23.8	19—26	22.5	T (20 : 31)	30—41	36.5	32—41	36.8
I′ (8 : 6)	22—25	23.6	21—29	24.8	U (30 : 22)	39—48	43.1	34—52	44.2
J (10 : 4)	30—36	32.4	31—33	32.2	V (9 : 12)	33—37	34.4	33—38	34.4
K (11 : 12)	23—30	27.1	20—31	27.0	W (4 : 8)	33—37	35.2	33—37	35.1
L (10 : 15)	28—33	30.0	27—33	29.8					
Total range	20—45		19—50		Total range	27—54		32—55	

Conclusively, so far as Japanese rajids are concerned, the teeth are not so important in taxonomy. The teeth similarly developed may have resulted from very similar food habits and related behaviors of the fish.

g. Color and pattern

1. Description in general

The color of integument in elasmobranchs is not usually so much conspicuous as in

the teleosts, but it considerably varies in species, and the characteristics in both color and pattern found in some sharks and skates have often been noticed. In fact, features of the color and its pattern on both sides of the body are subject to remarkable source for taxonomy of this group together with those of the spination, and are among the most convenient measures of distinguishing any particular species of rajid fishes. However, the character, on the other hand, has been known to change with the growth of the body to some extent even in a single species, and certain authorities have demonstrated that the variability of the character, which is known as metachrosis in a skate, is influenced by the physiological condition of the body (HOGBEN et al., 1936; ENAMI, 1936).

The present writer has examined in his present study, i) whether or not characteristics of the color and pattern developed on the skin of the body are useful in distinguishing species or groups of species of Japanese rajids, and ii) whether or not the characteristics in question of any group of species have any relation in the fish, and he has obtained a conception enabling him to conclude these questions.

2. Comparison of color and pattern

On the basis of color and its pattern found in both fresh and preserved specimens of Japanese rajids, young or old, which have hitherto been collected by the present author, the five following groups are conventionally recognized and called here groups 1 to 5. Group 1 involves the four species **A**, **T**, **V** and **W**, which have unitary color of either grayish brown or dark gray with no spot or pattern developed on the dorsum. But there are some differences in the ground color in these four species, viz., in the species **T** the dorsum is grayish brown though the color is lighter in the venter than in the dorsum, but the species **A** and **V** are lead-gray on both sides of the body, and the species **W** appears blackish gray on both surfaces. Group 2 is exemplified by the six species, **B**, **C**, **G**, **H**, **I** (**I′**) and **K**, their dorsums are characterized by having a common ground color of golden drab when fresh, but the color becomes lead-gray as the fish are preserved in the formalin solution. The color of venter appears white except the tail and marginal portions of the disc and the cloaca where they are dark brown. But, in the species **G** the venter is scattered by several large black blotches (G_1 in Fig. 66). Group 3 may be referred to the color found in the species **E** and **F**, the former being provided with a faint rosy color dorsally though the venter bears its color in very paler, while the species **F** is deep darkish purple on both sides of body. The ground color developed in these two species is rather stable even in their preserved condition. Group 4 involves five species, **D**, **J**, **L**, **O** and **P**, and they are dorsally of a complex hue with many spots and patterns of dark chocolate color, but the so-called pectoral ocellus is absent in the young stage except for the species **J**, in which two pairs of white marks are usually developed in the basal portion of the pectoral fins (Pl. I). The venter in these species is generally white excepting the marginal portions of the disc and the tail, where dark color and occasionally brown blotches are developed. Group 5, in which the six species, **M**, **N**, **Q** (**Q′**), **R**, **S** and **U** are involved, has the characteristics of the color and pattern which resemble those of the preceding group in having many variations in the character. But the fish of this group can be distinguished from that of the preceding group in having more or less developed pectoral ocellus margined with dark color, especially in their young stage. The venter is usually white, but occasionally several dark blotches are seen on it with the exception of the species **M**, in which the whole surface of the venter is covered with unitary color of gray.

Although there are some remarkable variations in detail other than those mentioned above in color and pattern developed on both dorsum and venter of the body of Japanese rajids, the features in every instance are too complex to be arranged in any clever system. Therefore, the author has deferred minute descriptions of the variations of the character in some species until he treated of taxonomy in this investigation later on.

Discussion

1). Systematic significance of the color and pattern of Japanese rajids

Rather extensive variations of the color and pattern are found to exist mainly owing to environmental and physiological factors, and the character is generally apt to be regarded as ignored in separating species in any group of fish. But it may be more or less important for the author to clarify whether or not these features are useful for critical identification of the species. As to various features of the color and pattern found in Japanese rajids, the following may be useful for discriminating species or groups with some certainty, i) whether or not the color of the integument is developed in unity or variety, ii) what kind of ground color is found on either dorsum or venter of the body in both fresh and preserved specimens ?, iii) presence or absence of any color mark or pattern, or of blotch on either surface of the body, and iv) presence or absence of the pectoral ocellus margined with either darker or fainter color especially in the young. Based on these categories, the annexed key to Japanese rajids has been arranged as a great help to the workers for their rapid identification.

1a. Color of dorsum unitary, with neither darker nor paler pattern.
2a. Group 1 : Dorsum gray or grayish brown in both fresh and preserved specimens.
3a. Dorsum grayish brown, but the venter is faint gray ..... *Raja tengu*
3b. Both dorsum and venter lead-gray or blackish gray .... *Breviraja tobitukai* (Pl. I; **A**); *Raja macrocauda*; *R. gigas*
2b. Group 2 : Dorsum golden drab in fresh, but it becomes lead-gray when preserved.
4a. Venter somewhat lighter than dorsum without dusky blotch, but marginal portions of disc, cloaca and occasionally of tail are developed with dark color .... *B. isotrachys*; *B. trachouros*; *B. parmifera*; *B. smirnovi smirnovi* including *B. smirnovi ankasube*; *Rhinoraja kujiensis*.
4b. Venter having several large dusky blotches ..... *B. aleutica* (**G**$_4$ in Fig. 66)
2c. Group 3 : Dorsum faint rosy or darkish purple in both fresh and preserved condition.
5a. Dorsum faint rosy when fresh, but venter is paler than the dorsum .... *B. diplotaenia*
5b. Dorsum darkish purple in both fresh and preserved condition .... *B. matsubarai*
1b. Dorsum rich in numerous spots and patterns of darker or lighter color.
6a. Group 4: Without pectoral ocellus margined with dusky color in young excepting the species **J**, in which a pair of white ring present on each side of pectoral fins; venter generally pale, but tail and marginal portion of disc dusky .... *B. abasiriensis*; *Rhinoraja odai* (Pl. I; **J**); *Rh. longicauda*; *Raja hollandi*; *R. macrophthalma*
6b. Group 5: pectoral ocellus margined with dusky color present on basal portion of each pectoral fin, being distnct in young.
7a. Venter generally gray ..... *R. kenojei* (Pl. II; **M**)

7b. Venter generally white excepting tail and marginal portion of disc inclusive of pelvic fins being dusky.

8a. Numerous spots of chocolate color scattered on dorsum .... *R. fusca*; *R. schmidti* (Pl. III; **S**)

8b. Color very variable, usually mottled with dark and yellowish brown .... *R. acutispina*; (Pl. II; **N**) *R. porosa meerdervoorti* (Pl. II; **Q**) inclunding *R. porosa tobae*; *R. pulchra* (Pl. III; **U**)

2). Relation between coloration and geographical distribution of the rajids

As regards the characteristics of color and pattern of the integument, the present writer has classified Japanese rajids into five groups which are introduced in Table 15, based on the four categories aforementioned.

Here, it is worthwhile to mention that these variations in species or groups of species are found to occur somewhat regularly with the changes of the habitat in both horizontal and vertical ranges. An example of such geographical variation of the character is found in the rajids inhabiting the sea off Aich Prefecture, the so-called Kumano-nada: the color and pattern of the fish change with the depth of the habitat. The vertical range of the depth of habitat, where any species of rajids is found, is from about 50 meters down to about 400 meters. Within this range a depth at which the color of the dorsum of a rajid changes from variety to unitary tone appears to be about 100 meters. The variety of the color and pattern of the integument of dorsum occurs above this threshold depth, though some variations of depth of the habitat of

Table 15. Characteristics of the color and pattern of Japanese rajid fishes classified into five groups. For abbreviations, see text.

Group	Characters: color tone	Characters: kinds of colors: dorsum	Characters: kinds of colors: venter	Pectoral ocellus	Species and subspecies
1	unity	grayish brown or lead-gray	light brown or gray or blackish gray	absent	A; T; V; W
2	unity	golden drab in fresh, lead-gray when preserved	white or black blotches present	absent	B; C; G; H; I (I'); K
3	unity	faint rosy or darkish purple	light rosy or darkish purple	absent	E ; F
4	variety	spots and patterns of dark chocolate present	white or faint gray	absent except species J	D; J; L; O; P;
5	variety	spots and patterns mottled with dark and yellowish brown	gray or white with or without dark blotch	present	M; N; Q; (Q') R; S; U

certain species were found according to vertical migration of the fish. For instance, the species **M, P, S** and **U**, which are involved in Group 4 or 5, are found to inhabit the region less than about 100 meters deep, whereas the species **A, T, V** and **W**, which are referred to Group 1, are found in the waters below that threshold depth, changing their vertical distribution from shallow to deep in order **T, A, V** and **W** (cf. Table 1). Species **J** may be an exceptional example to the trend mentioned above, because the color and pattern develop in this species, which inhabit the sea more than 300 meters deep in the neighbouring region (cf. Fig. 1).

Another instance which seems to show a good example of vertical change of the coloration has been observed in some rajids inhabiting the Pacific and the Sea of

Okhotsk, around Hokkaido. In these regions, the depth where the color and pattern of the integument change from variety to unitary tons seems to occur in rather shallow waters about 50 to 70 meters deep. Downward this threshold depth the color of the dorsum changes with the increase of the depth of habitat from species to species in order from unitary color of gray to golden drab and to faint rosy, and finally to darkish purple developed on both sides of the body. This final phase in the coloration is referable to the species **F**, which lives in very deep waters, so far as Japanese rajids are concerned (cf. Table 1).

Judging from these facts, the successive changes of the color and pattern with the increase of the depth of habitat of rajid fish may prove the principle concerning the protective or the concealing coloration (HUBBS, 1947; COTT, 1956), as in instances of other aquatic animals. Therefore, the characteristics of the color and pattern may be accounted for as an adaptive sequence with survival value in the niche of respective rajid species. As regards the unitary coloration of the deep-sea form without any color pattern, the characteristics in question may help critical identification of the species, because the light condition in the deep is very stable. However, when the niche of a species is restricted to shallow waters with a depth above the threshold in a region, the color and pattern of the skin of body are found to exist a very complex hue, which can be changed in a short time, being affected somehow through the sense of light. In fact, it has been noticed that many different color patterns are seen even in a single species of rajids inhabiting shallow waters, as in case of the species **Q**. By the way, this species has been given by TANAKA (1916) as a new species *Raja katsukii*, distinguished from *R. porosa* on account of its strikingly different color patterns (Pl. II; **Q**).

Conclusively, we should take care with delicate sense so as to use the features of color and pattern in the taxonomy of rajid fishes, as in the case of the teleosts and other aquatic animals in general. The writer surely believes that the color and pattern of the integument of rajid fishes are among the really phenotypical characters responsible for environmental factors regardless of phyletic relationship.

C. Sexual dimorphism

There is more or less pronounced sexual dimorphism in most groups of elasmobranchs, in which an outstanding sexual difference is the presence of the clasper in the male. Besides the clasper, the principal sexual dimorphism of subadult or adult rajid may be found in the following: total length of body, shape and length of snout, length of pelvic fin, length of tail, dermal denticles and teeth, and electric organ. These are summarized below one by one.

1. Usually the female is larger than the male to some extent as in other elasmobranchs. The difference in size between the two sexes, as a whole, is not so much conspicuous in the northern form as in the southern one. The greatest difference between the sexes of the same species has been found in the species **W**, the matured female of which is the largest (about 1800 mm in total length) in our rajids, measuring about 1.4 times as long as the male. So far as the species of Japanese rajids are concerned, sexual difference in total length of the adult fish may be seen in the following table.

These differences in size between the sexes may largely be correlated to differencial growth in the body, as explained on the snout and the tail of the fish.

2. Front margin of the body anterior to lateral angles of the pectoral fins is more

Table 16. Comparison of average total body-length of the adult in Japanese rajids. For abbreviations, see text.

Species, northern form	Total length, mm		Species, southern form	Total length, mm	
	male	female		male	female
A	430— 479	440— 507	M	564— 622	557— 660
B	810— 930	875— 900	N	400— 425	396— 435
C	900—1023	897—1070	O	411— 493	451— 540
D	622— 715	684— 714	P	315— 350	304— 365
E	820—850	791— 817	Q(Q′)	388— 440 (432— 480)	398— 425 (392— 495)
F	1063	1097—1165			
G	1106—1280	1470—1510	R	448— 517	470— 518
H	941	?	S	452— 507	492— 523
I (I′)	1030—1138 (902— 930)	1062—1160 (907— 943)	T	900—1020	1010—1130
			U	966—1052	962—1119
J	406— 480	458— 502	V	920—1000	1082—1250
K	894— 910	920—1043	W	1180—1345	1860
L	606— 688	602— 620			

or less undulated in the two sexes of matured male. The degree of undulation is more remarkable in the male than in the female, and the sexual dimorphism is more differentiated in the southern members than in the northern ones. Generally, the shallower the waters are where a species lives, the greater is the degree of undulation. The author may be justified in saying this, when he has found that the deep-sea forms, such as V and W, reveal lesser degree of undulation than the shallow-water ones, such as M, O, P and Q, even among those southern forms.

The degree of sexual difference in relation to the length of the snout is also witnessed between the two major forms of Japanese rajids, as illustrated in Fig. 25 and Table 6. In short, the length of the snout relative to the head is apparently longer in the female than in the male of southern forms with the exception of one species P, but this is not so obvious in the northern members except the species D, E, I (I′) and J (cf. Fig. 24 and Table 6).

3. Sexual difference can be seen in the elongation of the posterior lobe of the pelvic fin of the male, accompanied by the growth of the clasper. For this reason, in the length of disc the pelvic fin should not be included in making a comparison of the length of disc between the sexes. The remarkable elongation of the posterior lobe of the fin in the rajids is intimately attributable to the enormous development of the clasper siphon, embeded in the posterior lobe of the fin (cf. Fig. 2).

4. Sexual difference in the rajids especially of the southern form can also be seen more or less in the length of the tail, as shown in Fig. 32 and Table 7. The difference, however, is less conspicuous in many species of the northern form. Sexual difference in the length of the tail of the southern form seems to have been developed in close correlation with the electric organ and spines of the tail, mostly longer in the male than in the female.

5. Sexual difference in the spination is developed in two different ways, which contradict each other between the two major forms of Japanese rajids, viz., sexual difference of the northern form is revealed by the diminution of those downy prickles covering the disc, and the reduction of the spination with growth of the body is more

rapid in the male than in the female. On the other hand, in the southern form the difference is seen in the increase of spines in the tail with the growth of the body, and in most cases the degree of development of the spines becomes greater in the female than in the male. In both cases, however, it is common to the species that the alar spines are found to be developed more or less in the matured male, while the malar spines are developed only in the southern form except the species **W**.

In the male, the teeth on both jaws are well-developed with sharp pointed cusps, while in the female they are in pavement style with shorter cusps.

6. The electric organ of the male is more or less well-developed in most species of the southern form, when compared with that of the female. But there is no difference in the organ between the two sexes of the northern form. Some complicate structural evidence may exist in regard to the causal relation between the length of tail and the degree of development of the organ as well as of the spines on the tail. It is probable that the degree of development of the electric organ and the length of the tail are a negatively correlated between the sexes of the southern form.

V. Ecological and geographical reconnaissance on Japanese rajids

A. Age and growth of some rajids

It is essential to fishery biology for us to know how to find out the age of fish. Many biologists have long been trying to determine the age of fish, especially of teleosts, but no reports on elasmobranchs have been made public except the author's detailed studies in Japanese rajids (ISHIYAMA, 1951, 1957). The growth of the fish is closely related with their age, and the author has treated of it in this chapter, followed by some respects on fishery biology.

a. Age-determination

The age of fish is determined by three general methods, namely; length-frequency distribution, recovery of marked fish, and interpretation of the layers that are laid down in the hard parts of the fish (ROUNSEFELL and EVERHART, 1953, p. 297), the last of which is the most generally accepted method for this purpose.

Otolith and scales are used more frequently than the vertebrae in determining the age of teleosteans, but it is not so with elasmobranchs, so that only vertebrae are used in this pursuit, thus: concentric rings composed of different layers are constructed in the centrum, so number of rings as to the three kinds of rajids having economic importance, which belong to the so-called southern form, were pursued by histoloigcal method.

The author (1951) has already set forth his studies in *Raja fusca* and *Raja hollandi*, so it is intention to make a further study in *Raja kenojei**) in addition to the two species.

1. **Vertebrae to be used in the age-determination:** The vertebra in rajids has a clearly distinguishable centrum, whose size varies by the different positions of the

* The specimens were gathered at Shimonoseki fish market from Dec., 1952 to Sept., '53 in aid of the Shimonoseki Branch of Seikai Regional Fisheries Research Laboratory. The collection as well as preparation of the samples was carried out in assistance of Mr. Keisuke OKADA, to whom I wish to express my hearty thanks.

vertebral column, i.e. several centra situated most anteriorly, which are smaller than those posteriorly, are buried in the so-called anterior vertebral plate. Therefore, the centra have rather the constant measure in diameter and may be used in the age-determination, relating to the size of the fish, and are located at the range from 10th to 20th of the vertebral column (Fig. 54 R_1).

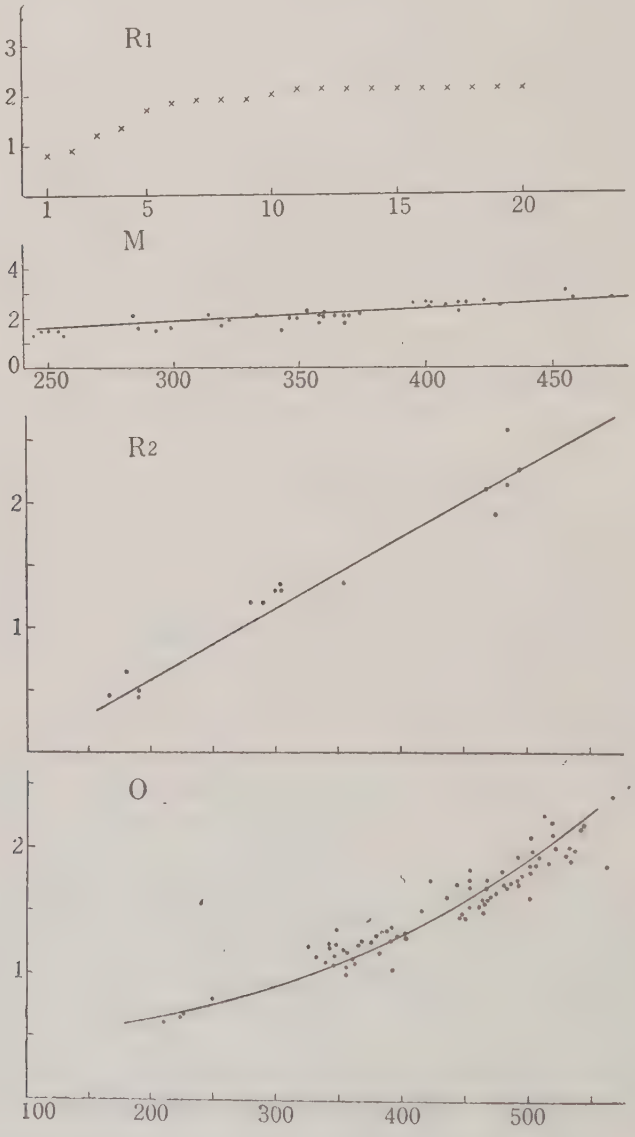

Fig. 54. Showing variation of the radius in mm of centra by positions ranging from the anteriormost to the twentieth of the vertebrae in R_1, and relations between the size of body and the radius of centrum in M, R_2 and O. Ordinate, radius of centrum (mm); abscissa, order of vertebral position from first to twentieth in R_1, and width of disc (mm) in M, but total body-length in R_2 and O. M, *Raja kenojei*; O, *R. hollandi*; R_1 and R_2, *R. fusca*.

2. **Growth of the centrum:** The present author has examined whether or not the centrum grows proportionally with the body. As shown in Fig. 55 the length of the centrum shown by the radius of the centrum (T) as in the case of teleosts seems to grow with proportional relation to that of the body, following fairly straight or curvilinear correlation (Fig. 54 M, R_2, O). From this fact, we have find that the growth of the centrum is more or less regularly related to that of the body of respective species, so that the following regression equations are given by means of the least square method in calculation for the three species;

Raja fusca, $T=0.0094\ L+0.19$ (mm),
R. hollandi, $T=0.30\ e^{0.0036\ L}$ (mm),
R. kenojei, $T=0.0061\ D+0.026$ (mm),

where e, D, L and T in the equations represent base of natural logarithm, disc-length, total body-length and radius of centrum, respectively. The equations are also conformable to those obtained from the cutting sections of the vertebral centra of the three kinds of rajids.

3. **Number of calcified concentric rings in the centrum in relation to size of body:** Longitudinal sections*) cut through the center of centrum of young rajids are seen in three different histological structures, viz., inner-, median- and outer-zone (1 in Fig. 55). The inner-zone, which is observed around the outside of the notochord, is characterized by having sparsely arranged cells. The median-zone is, however, made of minute calcified cells crowded together into a V-shaped narrow band, and is distinguished from others by thicker staining for the dye (haematoxylin) than elsewhere. The cells in the outer-zone are round or oval in shape, closely arranging to some extent.

On the other hand, the cross sections in the center of centrum take up with calcification in five different radials, forming a curious design (2 in Fig. 55). The dorsal radial among these calcified regions shows generally flat margin at the central part of the dorsal side, and moreover, the similar shape is found to continue from the center of the dorsal margin in the radial toward both extremities of the centrum. The other radials, lateral and ventral, are found irregular in outlines throughout the centrum. These facts are proved by the serial cross sections cut from the center of centrum to the intervertebral ring (i.r. in Fig. 55: 1).

Further, the median-zone in the longitudinal sections of the vertebrae taken from a specimen of the immature possesses one or more number of the bands, where the calcification becomes denser due to condensing cells than in surrounding tissue. The cells in the tissue of the outer-zone are also in a peculiar form observed as a layer, which is composed of many flat, or more or less lentiform, cells piling themselves in the middle portion of this zone. Apparently, this layer is somthing like the annual rings of plants. Moreover, this layer is observed to be connected with the denser calcified band of the median-zone curving upward from the central part to both anterior and posterior ends. These particular layer in the median- and outer-zones appear to be denser stained bands with the dye than the surrounding tissue.

In an adult rajid, the denser calcified layers found in the median- as well as in the outer-zone are calculated to be increasing in number from three to four, but three in most cases.

* The method of cutting section was pursued by the same technique as was used in the previous reports (ISHIYAMA, 1951), i. e. the materials were embeded the celloidin and stained by the haematoxylin-eosin solution after being cut in sections.

Thus, the number of calcified bands in the centrum increases with the growth of fish. These bands are observed as concentric rings of the centrum when viewed from the concave surface, known as tectospondylous vertebrae characteristic of the backbone of batoids termed by HASSE (1855).

Such being the case, the present writer has examined whether or not the number of rings of the centra taken from the different size-groups of the common skate, *Raja kenojei*, caught in December, June and September can be regarded as the annual rings, as seen in the other two kinds of rajids (l.c.).

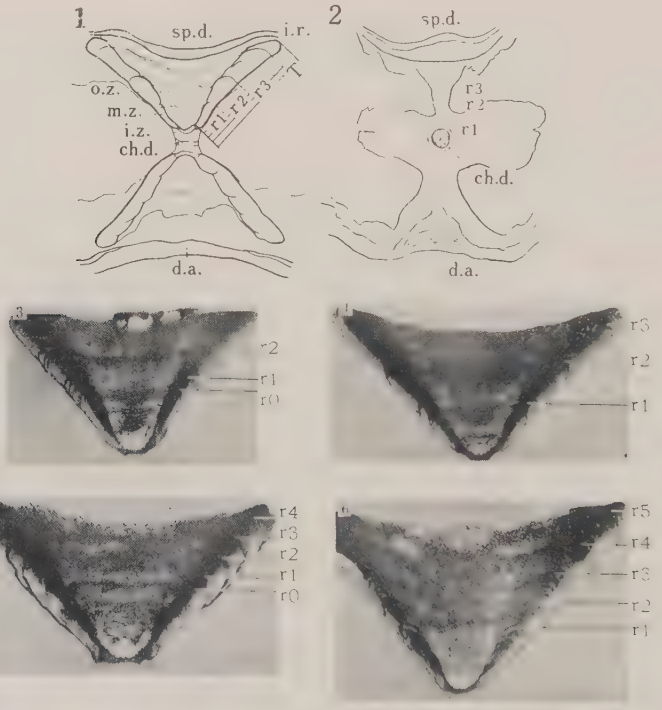

Fig. 55. Sections of the vertebral centrum of the skate, *Raja kenojei*, showing the method of measurement and terminology used in the age-determination, in 1 and 2, the former represents vertical longitudinal section along the center of the centrum, but the latter shows vertical cross section at the middle, and the photographs, 3 — 6, of the centrum representing various ages of the skate. ch. d., chorda dorsalis; d. a., dorsal aorta; i. r., intervertebral ring; i. z., m. z. and o. z., inner-, median- and outer-zone, respectively; r_0, r_1, ... r_5, rings corresponding respectively to ages; sp. d., spinal cord; T, radius of centrum.

4. **Radius of the ring in each ring class:** According to the writer's knowledge it is clear that the young skates, measuring less than 150 mm in total length, must have been hatched so lastly from the egg-capsules that the ring has not yet been found in the centrum. Then, supposing that the fish having no ring (r_0) is 0-age, 1-ring (r_1) is 1-age, and so on, n-ring (r_n) is n-age, the writer has measured the radius of ring in each ring class of the fish caught in different seasons. As shown

Table 17. Showing the radius of ring in each ring class of various size-groups of the skate, *Raja kenojei*, caught in three different months from the East China Sea.

Date of catch	No. of specimens	Age	Ring class, $r \pm \sigma$, mm					Total body-length, mm	
			r_1	r_2	r_3	r_4	r_5	range	average
Dec., 1952	2	I	0.93±0.02					336—372	354
	3	II	0.90±0.01	1.29±0.03				336—457	401
	5	III	0.73±0.07	1.26±0.11	1.66±0.20			444—631	514
June, '53	4	II	0,87±0.24	1.35±0.21				376—525	432
	3	III	0.83±0.04	1.16±0.17	1.50±0.22			364—510	449
	2	IV	1.05±0.03	1.37±0.02	1.69±0.03	2.06±0.02		587—596	591
	1	V	0.73	1.12	1.66	1.92	2.63		596
Sept., '53	6	II	0.95±0.10	1.42—0.14				431—547	494
	3	III	0.89±0.17	1.45—0.15	1.76±0.11			515—520	517
	4	IV	0.81±0.05	1.27—0.16	1.65±0.22	2.07±0.26		506—606	572
	(33) average, r_n		0.87±0.08	1.29±0.12	1.65—0.16	2.01±0.14	2.63		

in the following table, the distances r_n are nearly equal each other for the same number of n in average in the different size-groups. The same result was obtained in the other two kinds of skates treated previously.

Hence, we can easily assume the size of body of the skate when the radius of centrum becomes equal to that of the ring, computing from those figures and the equations mentioned above, as was done by LEA in the scales of teleosts.

Table 18. The calculated mean width of disc when the rings are formed in the centrum of the skate, *Raja kenojei*.

Age \ r_n, mm	r_1	r_2	r_3	r_4	r_5
I	157.9				
II	154.7	228.0			
III	149.8	214.9	273.6		
IV	149.8	218.2	275.2	342.0	
V	128.6	221.4	275.2	317.5	369.7

5. **Estimation on the season of ring-formation:** On the basis of the ratio between T and the difference from T to the length of lastest ring, that is T-r/T calculated in each age-class in the three different months.

It will be seen from the diagram that ring-formation lies in a period covering from January to May, when the water-temperature is relatively low in a year, and the eggs are spawned in this period. The same fact is also found to exist about the age-determination of the other rajid, *Raja fusca* (Fig. 56).

Judging from the above mentioned analysis, the concentric calcified rings of the centra of rajids that HASSE used as a basis for classification by the name of tectospondylous can be considered as a physiological character, which is regarded as the annual growth rings related closely with the water-temperature of environments where rajids live, or related with the physiological condition of the fish so far as the three rajid species are concerned, as is the case with the rings laid down in the hard tissues in many teleosts.

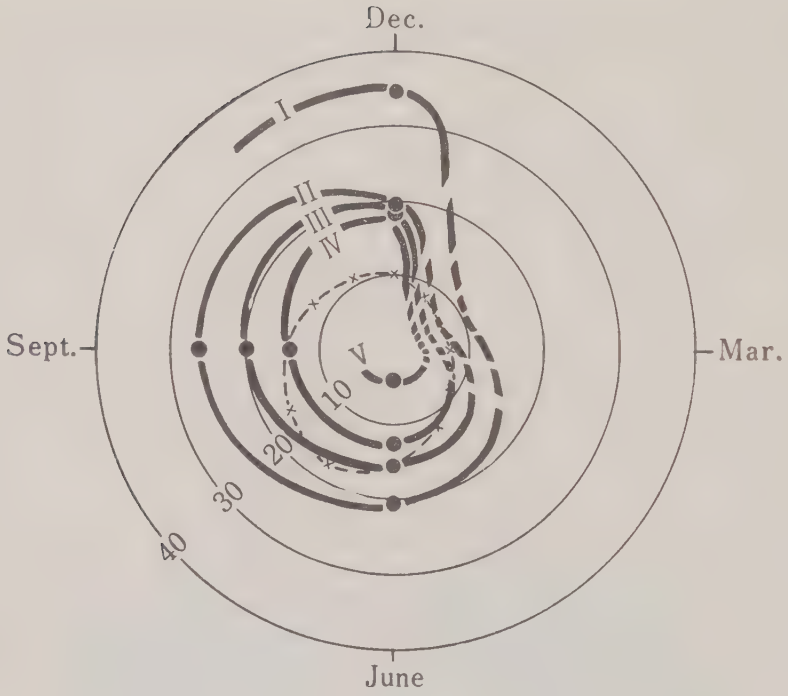

Fig. 56. Showing seasonal growth cycles of the rings in the centra of various sizes of the skate, *Raja kenojei*. Arabic numerals represent the growth percentage of the centrum, $(T\text{-}r/T) \times 100$, and also the temperature(°C) of the fishing ground; Roman numerals show the age of the fish. Brocken portion in the thickened line, which indicates successive changes of the age of the fish, covers the season of ring-formation suggested; the thin brocken line represents seasonal change of water temperature (°C).

b. Growth of the body

The term "growth" is here used to include the increase of size in the fish, and the animal body, in general. Strictly speaking, the growth means not only increase but also decrease in size of the body with chronological age of the fish, that is known as positive or negative growth. The growth includes, therefore, very complex problem, and is subject to different factors caused by both genetic and environmental conditions. Change in size and form goes on cojointly throughout the life of fishes with different rates of growth in development. Further, in the majority of animals, the various parts or organs of the body of any species have their own rate of growth, which has also been used in taxonomy as well as fishery biology.

Where the growth of fish is studied we should like to consider its close relation with age, because a comparison of sizes or parts between two forms of fishes may cease to have any validity without either chronological or physiological age, or both. When the age factor is taken into account, it becomes clear that the rate of growth is no constant, but differs with age and among species. But it is difficult to know the correct age of any particular form, still more difficult to do so about the deep-sea fishes like most rajids.

In the present scheme, therefore, the writer has intended to find out in a simple

and invariable way a body dimension which grows with age throughout the life-history of the fish than any other part where the growth is revealed in complex features. If such a dimension can be defined, it will be a substitute for the age of fish. And, if it is not difficult to measure the dimension, we can use it as the standard measurement in taxonomy and fishery biology so that the trend of growth may be compared simply and easily between any bodily parts or different species.

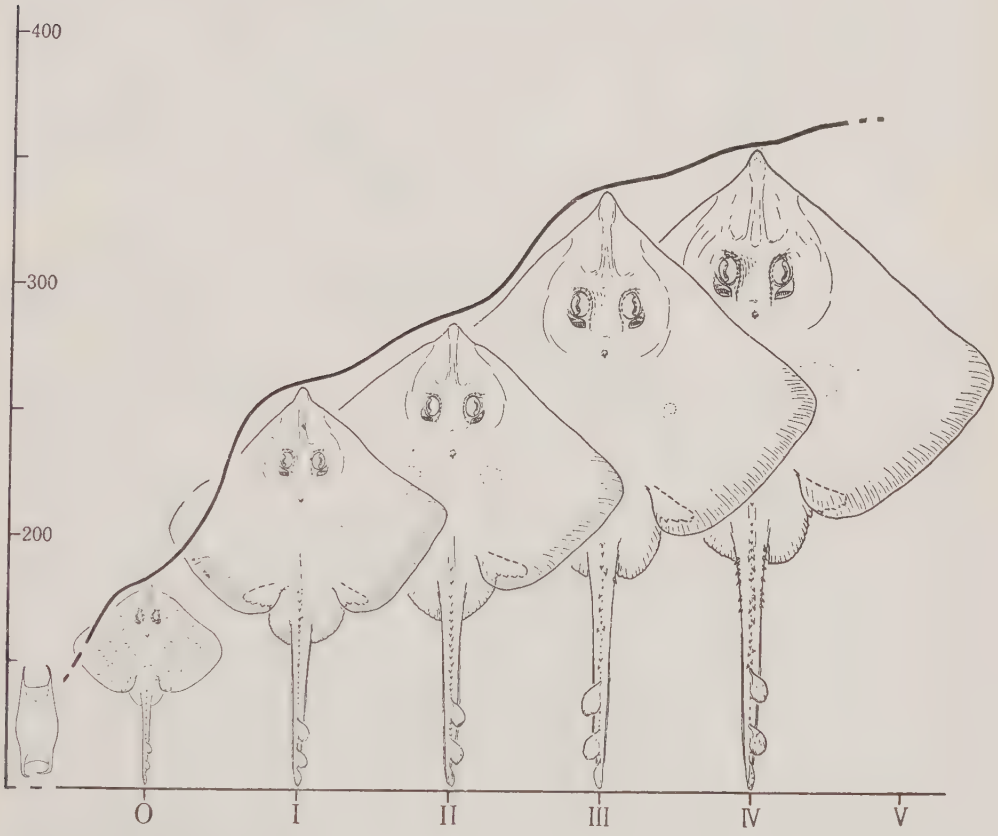

Fig. 57. Diagrammatic illustration of annual growth of the common skate, *Raja kenojei*, estimated from the rings formed in the centrums. Age, x-axis; disc-width (mm), y-axis.

Comparing the curve of Fig. 57 with that of Fig. 58, it is rather clear in the species (M) that the width of disc grows in more simple trend with age than the total length of body, which shows a complex curve in the growth. This differential growth in the respective dimension, viz., growth of the width of disc is considered to occur in direct relation with monosymmetrical increase in the pectoral fins which surves principally for locomotion; in other words, as KEARNEY (1914) in the growth of a dogfish and also by HAMAI (1940) in the carp, the parts holding a high percentage of musculature have necessarily the most intensive growth-rate on account of the massive growth of the musculature. On the contrary, the growth of total length is given rise to by various parts with differential growth-rates which change more or less during the life-history. This is the reason why the width of disc seems useful for the standard dimension, when relative growth of various bodily parts with age is

compared in different species.

It should be specially mentioned herewith that, in the annual growth of the width of disc that provides an exponential curve in the species (M) and probably in other rajids, the growth curve is well fit with WALFORD's growth transformation (WALFORD, 1946), and from this straight line the ultimate width of disc or the age may be computable as about 600 mm or six ages, which are well comparable with those presumed from actual landings of the fish of this species. But, the ultimate width of disc supposed from the curve calculated is somewhat less than that derived from WALFORD's

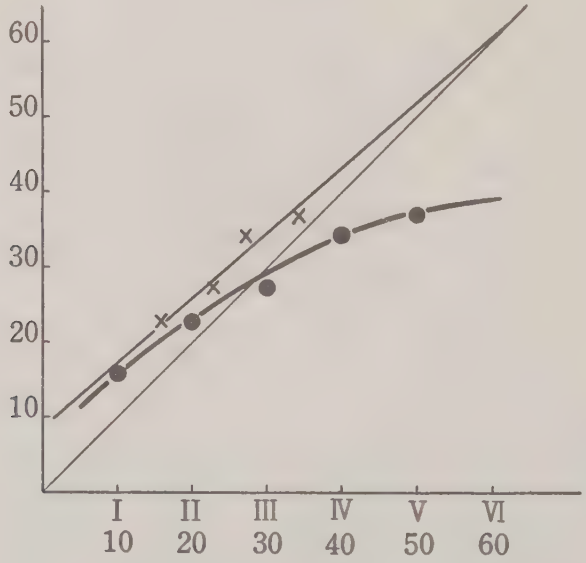

Fig. 58. Calculated age/disc-width relations of the skate, *Raja kenojei*, indicating by dotts on thickened curve, and by crosses on straight line transformed by means of WALFORD's method, where disc-width at ages 1, 2, ... , n are plotted along the x-axis against widths at ages at 2, 3,... , n−1 along the y-axis.

method. This difference in the two figures may be caused from the sampling method in age-determination used in the present study. In this connection, the calculation of the width of disc in relation to the age of fish has been summed up in amalgamation of the two sexes, though the female grows larger than the male even in the same age (cf. Fig. 73 and Table 16).

B. Zoogeographical remarks

In the following are briefly summarized some results obtained from geographical reconnaissance of Japanese rajids, to elucidate the faunal characteristics of this group of fishes in comparing them with those of the other representative regions in the world*).

1. Distribution of genera

As often recorded by the present writer, Japanese rajids are classified into three

* Division of major faunal regions of the sea is referred to EKMAN (1952) and SVERDRUP et al. (1955: The Ocean).

genera, which are found in the seas covering from the South China Sea to the Sea of Okhotsk. Of the three, *Rhinoraja* seems endemic to the deep seas of the Pacific, offing of the northern and middle districts of the main island of Japan, that is, the southern regions in the east Asiatic temperate region. But the genera *Breviraja* and *Raja* are cosmopolitic, being found in the Atlantic and the Pacific faunas. In Japan, however, *Breviraja* is more or less arctic as compared with *Raja* which is more or less a representative of the southern Japan.

The genera found in the seas around Japan and its adjacent regions are less numerous than those found in the Atlantic Ocean inclusive of the western and southern regions, which contain six, though we are still uncertain of the generic composition of rajids in the tropical Indo-Australian Pacific regions. It may be said, however, that Japanese rajids have poorer generic composition than those of the Atlantic basin, where the most numerous genera with highly diversification in features are found among all the representative regions of the world.

2. Distribution of species

Through the present study it becomes evident the 21 species and 4 subspecies of rajids are represented in the seas around Japan, attaining to twice as many species as hitherto been recognized. Of these, about half the number of species (**A** to **L**) are referred to the two genera, *Breviraja* and *Rhinoraja*, the so-called northern form, and the rest (**M** to **W**) are included in the genus *Raja*, the southern form. Geographically, the species referred to the former two genera seem to be in close relation with the cold currents, as the Oyashio and the Liman current, and the latter genus seems influenced directly by the warm current, the Kuroshio current. The boundary in distribution between the two forms corresponds fairly well with that found between the representative currents mentioned above. Namely, the northern form is distribtuted in the seas from the north of Hokkaido to the middle of southern part of Japan proper (Honshû), extending to off Kôchi in the Pacific and off Shimane Prefecture in the Sea of Japan. The southern form, on the contrary, is distributed from the shallow waters off northern districts of Japan proper to the South China Sea or to the deep seas off the middle of our main island (Honshû or Hondo), passing through the Tsugaru Strait, but the two species (**T** and **U**) are excepted, which inhabit the seas around Hokkaido. Thus, the geographical distribution of the two major forms of Japanese rajids is overlapped in northern and middle regions of Japan, as is found in the two currents. These facts agree well with those given by TANAKA (1931, pp. 22-25) in geographical distribution of Japanese fishes and other marine animals.

Although genera of rajids are rather few in number in the seas around Japan as aforementioned, species are rather numerous, when compared with those in other faunal area in the world*).

3. Consideration of faunistic features characteristic of the rajids found in the seas around Japan

On the basis of distributional pattern in both genera and species of rajids dealt with here, the characteristic features may be summarized in the following line: i) from a viewpoint of generic composition rajid fishes found in the Pacific are thought to be in close relation with those found in the Atlantic, because the two basins comprise the two common genera, which seem to be the leading stocks of modern

* As regards generic as well as specific composition of rajids hitherto found in the representative regions of the world, see the voluminous work done by BIGELOW and SCHROEDER (1953[b]).

rajids. However, according to JORDAN's theory (1925), the center of dispersal of rajids may be the Atlantic, where number of genera and species of this group are more numerous than those found in the Pacific, on the whole; ii) the rajids found in the North-western Pacific may have closer affinity to those found in the North-Eastern Pacific than to those of any other part of the Pacific region, though we are still lacking in the details of systematic composition of this group from the latter region.

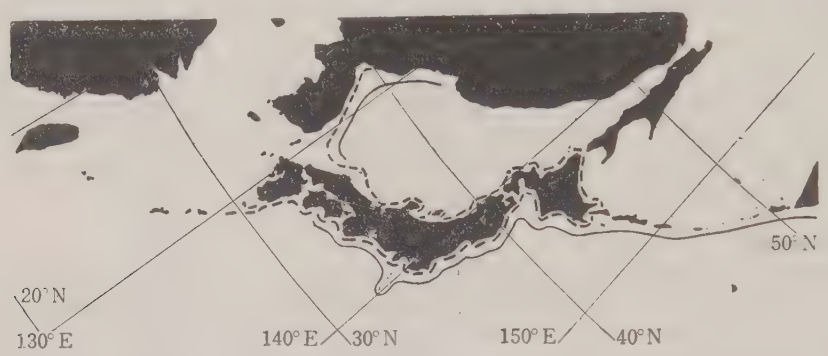

Fig. 59. Total range of rajid fishes found in the seas around Japan, showing distributional patterns of the two representative forms. Unbroken line, northern form; broken line, southern form.

For instance, the two species (G and H) of the northern form are common in the seas off northern Japan and Alaska as well as in the North American waters, although the identification of these two species is still more or less doubtful. Probably, some rajids of the northern form found in the northern Japan may also be found to inhabit the North-eastern Pacific region, which belongs to the arctic faunal region together with the North-western Pacific one. If so, it may be said that the rajids in the two different regions may have arisen from a congeneric stock, and may have been differentiated in their own evolutional pattern on the two sides of the North Pacific; and iii) it is a striking evidence that in Japanese rajids, almost all members of the northern form and the whole of the southern one are endemic, and that the two forms in the waters around Japan are well balanced in the number of species, although both forms may have arisen from the common ancestral stock in the northern waters. These facts are presumed to have been caused, powerfully influenced by the two main currents, the Kuroshio and the Oyashio.

As regards the biogeographical differentiation in minor ranks, they shall be discussed in the systematic part.

VI. Taxonomy

Family Rajidae

The diagnosis of the present family was so completely given by BIGELOW and SCHROEDER (1953b) on world-wide basis of the study that there seems no room for the neccesity of newly adding to the description.

The Japanese rajid fishes has classified into three genera, i.e. *Raja*, *Breviraja* and *Rhinoraja*, the last of which is thought to be endemic to the waters around Japan, but other two may be cosmoplitic as already mentioned.

Although the present family should be subdivided genealogically into higher ranks above those genera heretofore erected by various authors it may be wise to reserve for future study untill more compact knowledge of the fish shall be accumulated with world-wide study.

The following key to the Japanese genera is based on both external and internal features which seem to be merit for the fundamental importance of each genera.

Key to genera of Japanese rajids

1a. Snout with hard axis in touch, bearing distinct rostral ridge. Disc always longer than tail with less number of counts of precaudal vertebrae, ranging from 36 to 61. Electric organ more or less well-developed with disc-form elements, extending from tip to near or beyond the base of tail (Fig. 30). Rostral cartilage stout, projecting from skull in a rod- or tape-like bar, inserted by rostral appendices or wings at the anterior extremity of the cartilage; posterior ends of the wings free or very close to lateral sides of rostral cartilage. Radial cartilages of pectoral fins apart far from lateral sides of the wings, leaving more or less broadly developed semicartilaginous tissue in the snout (Fig. 27). Clasper usually depressed dorso-ventrally, bearing complex structure (Types 8—13)..... *Raja*

1b. Snout very soft and flexible without clear rostral ridge. Disc usually shorter than or nearly as long as tail with some exceptions; precaudal vertebrae numerous, ranging from 63 to 91. Electric organ composed of cup-form elements, covering from tip to near middle of the tail (Fig. 30). Rostral cartilage very feeble, developed from skull in slender tape- or bar-like projection, inserted anteriorly by rostral appendices, posterior ends of which are apparently free from lateral sides of rostral cartilage. Radial cartilages of pectoral fins closely contact with the rostral appendices (Fig. 28). Clasper usually cylindrical, taking rather simple structure of glans (Types 1—7).

2a. Rostral cartilage without segment (Fig. 26 **B**). Tail usually almost as long as or slightly longer than disc, but when tail bears relatively large electric organ (Fig. 35 **H, I**) the disc more or less longer than tail even when provided with numerous precaudal vertebrae ranging from 63 to 87 ..... *Breviraja*

2b. Rostral cartilage with a segment (Fig. 26 **K**). Tail always longer than disc, bearing small electric organ (Fig. 35 **J, K, L**) and numerous precaudal vertebrae with range from 74 to 91 ..... *Rhinoraja*

Breviraja BIGELOW and SCHROEDER 1948, emend

Breviraja BIGELOW and SCHROEDER, Jour. Mar. Resser. 7 (3): 231. Genotype; *Breviraja colesi* BIGELOW and SCHROEDER, 1948, Atlantic species.

The diagnosis of the present genus may further be emended so as to add following characters which were already given in part by the present author (1952): Whole dorsal surface of disc and tail furnished more or less with prickles or thorns bearing stellate bases when born, thenceforth the scales become more setose or smooth with growth of the body. Snout very soft, without clear rostral ridge when touch. Tail usually slender, elongated (Round-type), nearly as long as or longer than disc. Rostral cartilage delicate, projecting foreward from skull, with a slender tape- or bar-like cartilage, which bears anteriorly a very thin rostral appendix on each side; the appendix hanging posteriorly with distal part free from lateral side of the rostral cartilage (Fig. 28). Radial cartilages of pectoral fins stand very close to the rostral appendices. Clasper usually cylindrical (Club-type), with or without pseudosiphon on posterior dorsum; structure on inside border of the glans rather simple, avoiding the development of rhipidion and shield (Figs. 3 and 4); but the cartilages show ideomorphic feature (Figs. 12 and 13). Precaudal vertebrae numerous, covering 63 to 88. Electric organ composed of cup-form elements, running from tip to midway of tail (Fig. 35). Egg-capsule usually bearing long horn on each four corner with slit located at midway or near distal tip of the horn; capsule-wall composed of two layers, having rough surface in most cases.

It is wiser to treat Japanese species referable to the present genus by subdividing into three subgenera on the basis of following points, thus; feature of spination, number of abdominal and precaudal vertebrae, structure of glans clasper, relative length of tail in relation to degree of development of the electric organ, and features of egg-capsules.

Key to subgenera of the genus *Breviraja*

1a. Tail much longer than width of disc; abdominal vertebrae relatively few, measuring below 30; characteristics of glans clasper, Type 3; electric organ very small; egg-capsule with smooth surface ..... *Notoraja*, n. subg.

1b. Tail shorter than width of disc; abdominal vertebrae numerous, being above 30; characteristics of glans clasper, Types 4—7; electric organ moderately large; egg-capsule with rough or rather rough surface.

2a. Tail greater than 70% of width of disc; dorsal surface of disc setose or almost smooth when matured; electric organ moderately developed, usually polygonal in cross view; precaudal vertebrae less than about 80; clasper is of Types 4—6; egg-capsule equipped with long, whip-like horns and roughened with pungent spines .... *Bathyraja*, n. subg.

2b. Tail less than 60% of width of disc; dorsal surface of disc largely smooth in the adult; electric organ relatively large, roundish in cross view; precaudal vertebrae more than about 80; clasper is of Type 7; egg-capsule bearing flattened horns and rather roughened with minute ridges running lengthwisely..... *Arctoraja*, n. subg.

Notoraja, n. subg.

Body entirely covered with numerous prickles on dorsal surface, but ventral side wholly smooth; snout, soft and flexible, projecting forward with blunt tip. Tail exceedingly long, longer than half the total length of body or than width of disc; procaudal portion rather long, with distinct caudal fin prickled. Pelvic fin deeply notched with slender anterior lobe. Rostral cartilage much slender, inserted anteriorly by long rostral appendices which reach to near midway point of the rostral cartilage. Anterior fontanelle large, triangular in shape. Abdominal vertebrae quite different in number from other

members of the genus *Breviraja*, measuring 24—27. Structure of glans clasper is of peculiar, Type 3. Electric organ very small in both size and number of elements. Egg-capsule with very smooth surface and long roundish horn on each corner.

Type species: *Raja tobitukai* HIYAMA, 1940

Notes: The present subgenus differs rather widely from *Bathyraja* and *Arctoraja* as given in the foregoing key, especially in having such fundamental characters as less abdominal vertebrae and specialized clasper organ, which serve in establishing this new subgenus. Only one species is referred to this subgenus, with limitted range in the habitat from the southernmost region within the seas inhabited by the northern members.

Breviraja (*Notoraja*) *tobitukai* (HIYAMA)

(Abbreviated as **A**; Japanese name, Tobituka-ei)

Fig. 60; Pl. I, A

Raja isotrachys MATSUBARA (non GÜNTHER), 1936, p. 23, Kumano-nada (key).

Raja tobitukai HIYAMA, 1940, p. 169, fig. 1, Kumano-nada (original description). —— KAMOHARA, 1952, p. 10, off Kôchi.

Breviraja tobitukai ISHIYAMA, 1952, p. 1, fig, 1, Kumano-nada (key). ——ISHIYAMA, 1955, p, 271, figs. 1,3,4, Kumano-nada (electric organ). ——ISHIYAMA and KUWABARA, 1955, p. 87, figs. 1-4, Kumano-nada(electric organ).——Matsubara, 1955, p. 138, Kumano-nada (key).

Materials examined: 22 specimens, 374-507 mm in total length, and 4 egg-capsules, deep sea (300-400 m in depth) off Aichi and Shizuoka Prefectures; 1940—1953.

External: Snout very soft, flexible and pointed only at the extremity, proportion of which 2.03-2.20 and 2.10-2.26 times into head in male and female, respectively. Eye very large, longer diameter greater than interorbital width and about 2 times into snout-length; iris lapet absent. Tail remarkably long, much longer than width of disc; precaudal almost equal to or trifle shorter than length of disc; procaudal rather long, about as long as preoral length in most case; lateral folds of tail distinct, run from root to tip of tail. Anterior lobe of pelvic fin slender, bearing a deep notch between it and the posterior lobe. Caudal fin distinct, about as long as eye.

Prickles uniformly developed on entire dorsal surface without noticeable enlarged thorns, no sexual differences in spination but in matured male, pelvic fins without prickle and pectoral fins armed with backler spines opposite being the case with matured female; dorsal and caudal fins all setose, but under surface of body smooth; somewhat thickened prickles set along mesial line of tail (Fig. 60 A_1).

Color on both sides uniform gray without any pattern (A in Pl. I).

Internal: Rostral cartilage very feeble and long; rostral appendices also very long and thin, reaching as far posteriorly to near middle of rostral cartilage. Anterior fontanelle of cranium long, triangular in shape; posterior one elongated with shallow constriction at the middle portion (Fig. 28 **A**).

Vertebrae in abdominal and precaudal portions comparatively few in number, ranging 24-27 (25.5 in average) and 63—70 (65.6 in average), respectively (Figs. 43 and 44: **A**).

Intestinal valves much fewer than in any other species referred to the genus, covering 5-6 (5.7 in average), (Fig. 48 **A**). Heart valves set in four series in three rows as in other species of this genus (Fig. 51 **A**).

Clasper specialized in its glans, in having knife modified from accessory terminal

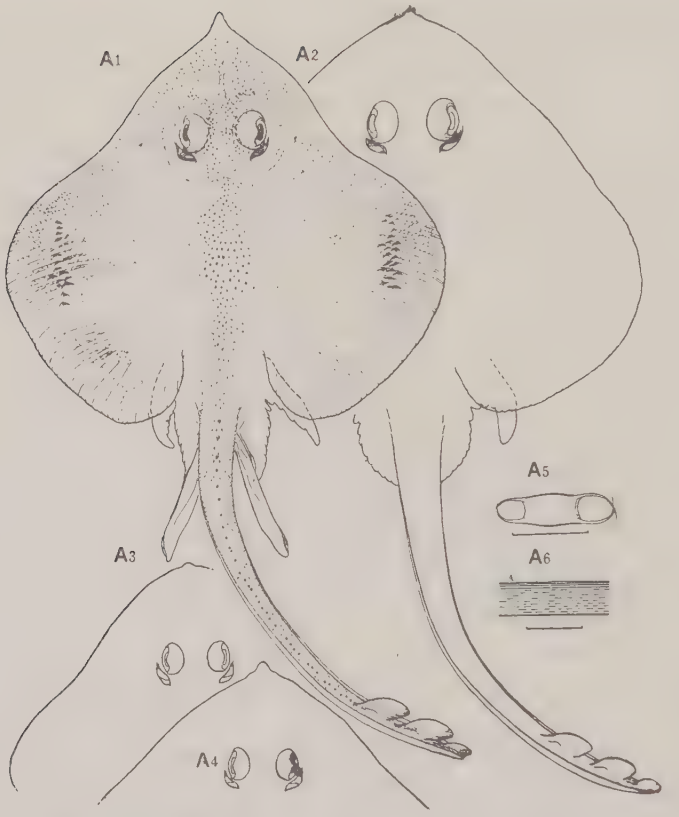

Fig. 60. *Breviraja tobitukai* (HIYAMA); A_1, adult male (473 mm); A_2, adult female (507 mm), prickles omitted; A_3, subadult male (473 mm); A_4, subadult female (412 mm); A_5, egg-capsule, scale 5 cm; A_6, section of capsule-wall, scale 0.2 mm. $A_{2,3,4}$ showing differences in outline of body or anterior portion between adult male and female or the younger fishes. All these specimens were taken from the Kumano-nada.

and having claw and pela on ventral lobe, Type 3 (Figs. 4 and 12: **A**).

Developmental stages: One adolescence is available in the present study, but the knowledge on the young is still scanty. It should be noted herewith that the features as well as the proportion of snout are markedly change when matured in male, but the phenomena are not so conspicuous in the female even in the adult (A_{1-4} in Fig. 60).

Egg-capsule: (Type 1); very small, translucent when fresh, characterized by having very smooth surface, long whip-like projection at each four corner and monotypic structure of the wall, all of which are considered to be generalized characters ($A_{5,6}$ in Fig. 60).

Notes: This species was first added to Japanese rajids by HIYAMA (1940) from Kumano-nada off Aichi Prefecture. But the range in distribution of the present species seems to be confined to the deep sea, offing from Kôchi to Shizuoka Prefectures (Table 1), where the animal is rarely found in the landings of the trawler, and the range mentioned above is thought to cover the southernmost part in the region where the

northern form inhabits. On the basis of the characters in both external and internal as mentioned above, the present species seems to maintain rather generalized features as compared with the relatives. Thus, we may be able to agree here with a view (BRIGGS, 1955, p. 157) on geographical distribution and differentiation in the animal that the most primitive form occurs on the periphery of the area inhabited by the family.

The present species resembles species J in general appearance, especially in having long tail, numerous prickles without noticeable modification, but the two species are quite distinct from each other in the fundamental characters, such as the rostral cartilage, counts of precaudal vertebrae and structure of glans clasper.

Bathyraja, n. subg.

Dorsal side of disc entirely prickled or partly setose when matured, but ventral surface usually naked with a few exceptions; enlarged thorns usually present on nuchal and shoulder regions, and on mesial line of tail. Snout bluntly elongated in more or less extent, and soft, flexible in touch. Tail long, slender and rod-like in general outline (Round-type), about as long as 70% or more of disc-width; procaudal portion moderate in length, leaving rather distinct caudal fin. Pelvic fin notched more or less.

Rostral cartilage slender, tapers in its main portion, which shows serpentine form in some species; rostral appendices characteristically develop in various degrees (Fig. 28). Shape and location of anterior fontanelle vary specifically. Abdominal and precaudal vertebrae ranging 31-38 and 66-82, respectively. Electric organ moderately developed. Clasper is of Types 4-6, taking with ideomorphic feature. Egg-capsule roughened in greater or less degrees, bearing very long, whip-like horns (Type 4).

Type species: *Raja isotrachys* GÜNTHER, 1877

Notes: The present subgenus seems to involve some variants, but they agree well with each other in some fundamental characters, such as trend in development of prickles and enlarged thorns, and in egg-capsule, and features of rostral cartilage and its appendices, number of vertebrae in both abdominal and precaudal portions, proportional length of tail closely relating to the degree of development of electric organ, and tendency in transpecific specialization of structure of clasper. On the basis of these characteristics the present author established this new subgenus so as to make clear from other subgenera in the genus *Breviraja*. The present subgenus includes annexed six species, in which one is recorded herein as new to science.

Key to species of the subgenus *Bathyraja*

1a. Dorsal surface of disc entirely rough with numerous prickles or partly smooth even in the adult; enlarged thorns more or less well-developed on both nuchal and shoulder regions.

2a. Snout broad and elongate, about half times as long as head; dorsal surface entirely rough with numerous prickles, but smooth the ventral; nuchal spines 3-5, intermitted from those setting on tail; ventral surface without distinct black blotches. Rostral cartilage slender, rod-like in shape, about as long as or shorter than cranium.

3a. Dorsal surface of disc uniformly covered with numerous minute prickles in both males and females; nuchal and shoulder thorns usually distinct. Rostral cartilage about as long as cranium (**B** in Fig. 26); intestinal spiral valves 10-11 (10.6 in average). Clasper representing Type 4 (**B** in Figs. 4 and 12), characterized by having rudimentary pseudosiphon (Type-Ps^2) ..... *isotrachys* (Fig. 61).

3b. Dorsal surface of disc entirely roughened with rather thickened prickles, which are somewhat sparse on basal portion of pectoral fins in matured male; both nuchal and shoulder thorns more or less obscure. Rostral cartilage shorter than cranium (C in Fig. 28); intestinal spiral valves 8-10 (9.0 in average). Clasper structure is of Type 5 (C in Figs. 4 and 12), distinct from that of preceding species in absence of pseudosiphon and in having much reduced dorsal terminal 1 .... *trachouros*, n. sp. (Fig. 62)

2b. Snout long, rather accumulated, more than half times as long as head; disc wholly furnished with very small prickles on both surfaces; large thorns developed on shoulder and nuchal region, to which those setting on mesial line of tail are continued in a row; ventral surface bearing some black blotches, Rostral cartilage tapers, meandering in serpentine form in most cases (G in Fig. 28). Clasper, Type 6 (G in Figs. 4 and 12), distinguished from those of relatives in having much simple structure and reduced ventral terminal ..... *aleutica* (Fig. 66)

1b. Dorsal surface of disc greater or less smooth when matured, but armed with more or less well-developed prickles overall in young, enlarged thorns present or absent on nuchal, and absent on shoulder.

4a. Enlarged thorns usually absent or very few, if present, on nuchal region; dorsum of disc setose on anterior marginal, orbital and mid-belt portions, to which prickles developed on tail are continuous, covering in a band. Ventral surface wholly white with or without dark ring margined cloaca. Rostral cartilage long, about as long as cranium; rostral appendices much shorter than half the length of rostral cartilage (Fig. 28). Intestinal valves 8—11. Egg-capsule armed with numerous prickles without cover of heavy thread-like tendrils.

5a. Pelvic fin moderately notched; nuchal spine absent, but caudal ones present at places in a row. Dorsum of disc grayish brown, with irregular patterns. Precaudal vertebrae 66—70 (67.6 in average), and intestinal valves 8—9 (8.2 in average). Clasper, Type 5 (D in Figs. 4 and 12), characterized by having remarkably reduced dorsal terminal 1 without pseudosiphon .... *abasiriensis* (Fig. 63)

5b. Pelvic fin deeply notched; nuchal spines absent or a few, if present, ranging 1—3 (0.35 in average), but caudal ones usually distinct, setting regularly in a row. Dorsum of body uniformly faint rosy or dark chocolate, without any peculiar color patterns. Clasper is of Type 6 (E in Figs. 4 and 12), characterized by having rather small pseudosiphon and specialized accessory terminal 2 .... *diplotaenia* (Fig. 64)

4b. Nuchal thorns distinct, usually 3—6, well-developed. Dorsum of disc largely smooth, but small areas on anterior marginal, orbital and mid-belt regions armed with prickles, with which prickles covering on tail are continuous, running in a band. Both surfaces of body darkish purple. Clasper, Type 6 (F in Figs. 4, and 12), especially notified with large pseudosiphon and long accessory terminal 2. Egg-capsule much specialized in having heavy cover of thread-like tendrils over prickly surface ..... *matsubarai* (Fig. 65)

Breviraja (*Bathyraja*) *isotrachys* (GÜNTHER)
(Abbreviated as **B**; Japanese name, Soko-gangi-ei)
Fig. 61

Raja isotrachys GÜNTHER, 1877, p. 434, southern Japan (original description). —— 1887, p. 7, Pl. 3, lat. 34° 7' N, long. 38° E. —— JORDAN and

Snyder, 1901, p. 42, (reference). —— Jordan and Fowler, 1903, p. 649 (compiled). —— Tanaka, 1927, p. 670, fig. 430, Hokkaido to northern Japan. —— Jordan and Hubbs, 1925, p. 93, northern Japan (key). —— Fowler, 1930, p. 354 (reference). —— Matsubara, 1935, p. 44, (in Japanese) (key). —— 1936, p. 22, (in Japanese) fig. 13 (compiled). —— Okada and Matsubara, 1938, p. 23 (in Japanese) (key). —— Fowler, 1941, p. 379 (reference). —— Ishiyama, 1950, p. 30, figs. 1 and 2, Sea of Japan and coast of Hokkaido (egg-capsule); 1950—1951.

Raia isotrachys Garman, 1913, p. 354 (compiled).

Breviraja isotrachys Ishiyama, 1952, p. 9, fig. 2, Sea of Japan and northern Japan (key). —— Honma, 1954, p. 2, Sea of Japan (listed). ——, 1955, p. 218, Sea of Japan (listed). —— Ishiyama, 1955, p. 271, figs. 2—4, northern Japan (electric organ). —— Matsubara, 1955, p. 139, northern Japan (key).

Materials examined: 34 specimens (209—930 mm in total length) and 4 egg-capsules; deep seas off middle of Japan and coast of Hokkaido; 1940—1950.

External: Snout broadly elongated with rather straight lateral margins, nearly half as long as head, being trifle greater in the ratio in male than in female (**B** in Fig. 24). Eye moderately large, the diameter on longer axis a little smaller than interorbital width, which is 3.2 to 3.8 times as long as snout. Tail rod-like in general form (Round-type), almost as long as disc, but shorter than the disc-width, being 1.2—1.8 times in the latter (**B** in Fig. 31). Pelvic fin moderately notched; two dorsals subequal, the longest dimension about one-fifth the length of head; caudal fin usually distinct as a small flap.

Doral surface of body wholly armed with numerous minute prickles without noticeable reduction even in the adult; 2—6 and 1 thorns developed respectively on nuchal and shoulder regions, in most cases, and a row of 18—28 enlarged thorns also along mesial line of tail; dorsals, caudal and pelvic fins prickled. Ventral surface of body entirely smooth.

Prior to preservation dorsum golden drab, but it becomes grayish brown after preservation, without any particular color pattern; ventral side of body white, excepting tail, where a few dusky bands are found in some cases. (Fig. 61 $B_{1,2}$).

Internal: Rostral cartilage long, elongated anteriorly, about as long as cranium; rostral appendices extending as far posteriorly to about one-third the way to base of rostral cartilage. Anterior fontanelle large, elliptical in shape, followed anteriorly by a small slit in some specimens; posterior fontanelle long, strongly constricted medially (**B** in Fig. 26).

Vertebrae as many as 34—40 + 73—82. Intestinal spiral valves 10—11 (10.6 in average). Heart valves mainly 4 in a row (**B** in Fig. 51).

Electric organ medium in size, pertaining fundamental structure in the electric elements of northern form (**B** in Fig. 35).

Clasper is of Type 4, especially peculiar in possessions of half vestiged pseudosiphon and large dorsal terminal 1 (**B** in Figs. 3, 4 and 17).

Developmental stages: Proportional length of snout in young almost the same as in the adult (**B** in Table 6), but that of tail more or less different between the two stages, being the tail about as long as disc-width in the young (**B** in Table 7).

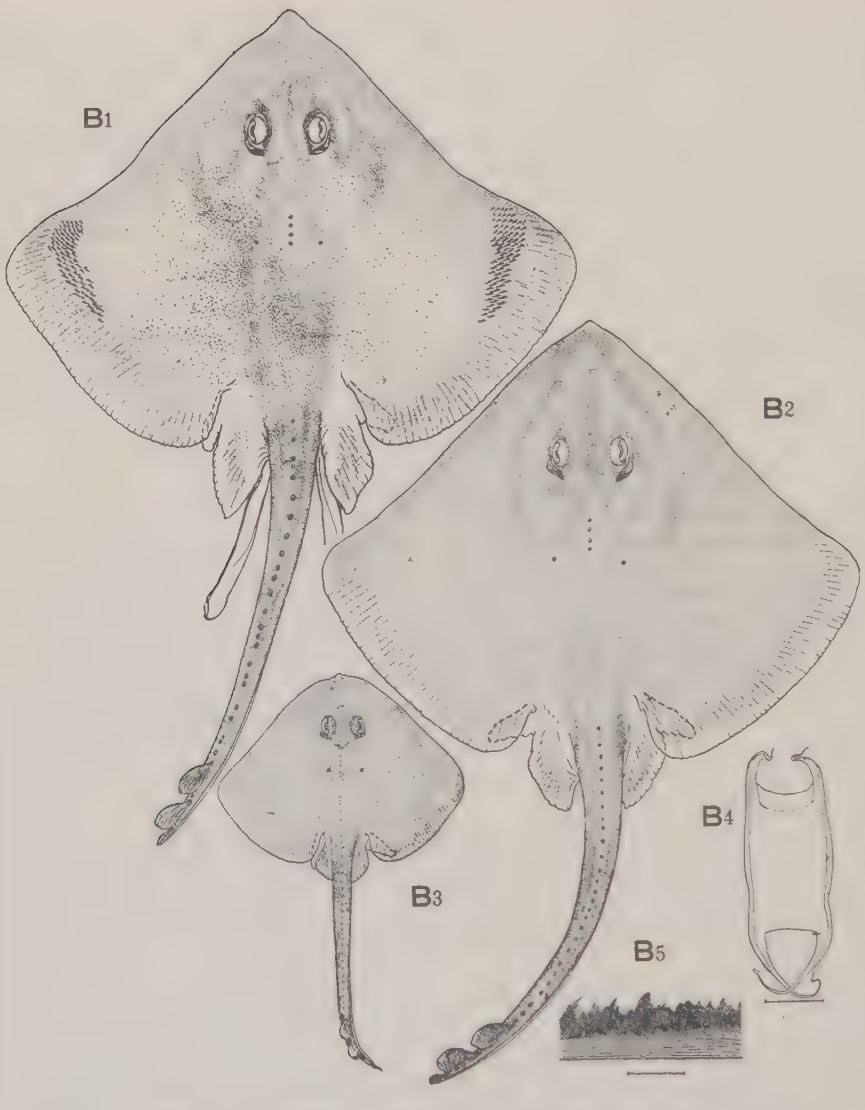

Fig. 61. *Breviraja isotrachys* (GÜNTHER): B_1, adult male (930 mm); B_2, adult female (875 mm); B_3, young male (209 mm); B_4, egg-cupsule, scale 5 cm; B_5, section of capsule-wall, scale 1 mm. All these specimens were taken from the Okhotsk Sea, off Monbetsu and Wakkanai, Hokkaido.

Egg-capsule: Capsule is of Type 4, large, characterized by having long horns and rough surface with numerous minute prickles ($B_{4,5}$ in Fig. 61).

Notes: So far as is known to the writer the present species seems to inhabit the northern waters around Japan, covering the main island northward of middle region, i.e. from off Shimane Prefecture (the Sea of Japan) and Chiba Prefecture (the Pacific) to north of Hokkaido (the Sea of Okhotsk). In the southern area within this region, the depth of habitat usually exceeds 200 meters, but it becomes shallower, about 100 meters or shallower in the north.

Since GÜNTHER (1877) has recorded first this species from south of Japan very

few confusions in its identification were encountered with some ichthyologists on account of being very common in the northern waters, and having rather conspicuous features in the first sight. However, the present author found an another one which closely resembles the present species, and the comparison between the two will be given in detail with annexed species.

Breviraja (*Bathyraja*) *trachouros*, n. sp.
(Abbreviated as C; New Japanese name, Zara-kasube)
Fig. 62

Materials described: Holotype, 900 mm, off Erimo Peninsula, Hokkaido, May 19, 1951; paratypes, 30 specimens (230—1023 mm in total length) and 5 egg-capsules, off Kushiro and Muroran in Hokkaido, and off Same and Shiogama in northern Hondo; 1950—1951.

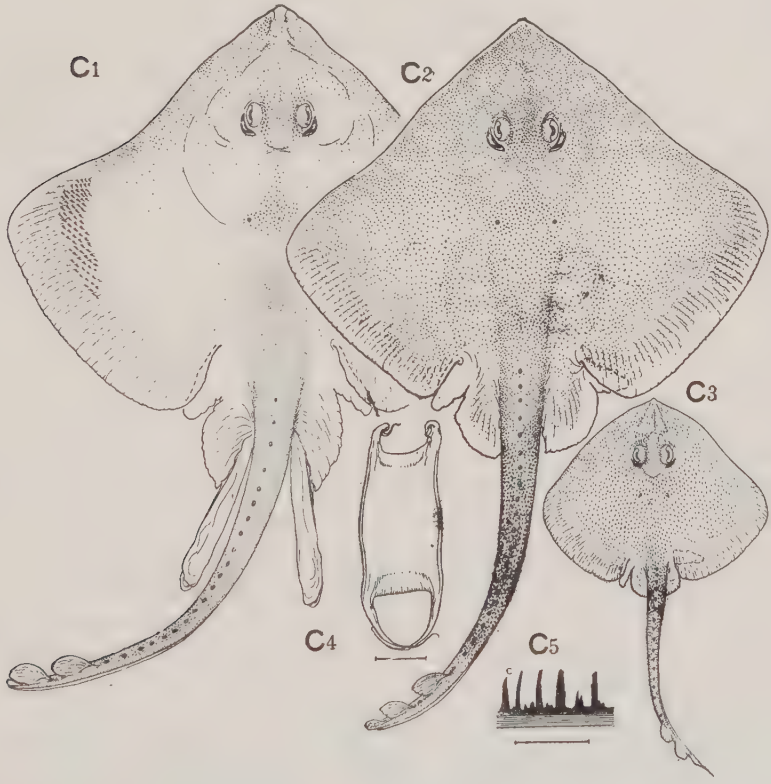

Fig. 62. *Breviraja trachouros*, n. sp.: C_1, holotype, adult male(900 mm); C_2, adult female (835 mm); C_3, young female (230 mm); C_4, egg-capsule, scale 5 mm; C_5, section of capsule-wall, scale 1 mm. All these specimens were gathered at Same fish market, being taken from off the Erimo Peninsula.

External: Disc-length 2.05, width 1.58, tail 1.83 in total length; head 1.95, snout 4.18, precaudal 1.13, preoral 1.53 in disc-length. Snout 2.15, 1st and 2nd dorsal 4.15 and 4.56, respectively, and caudal fin 10.70 in head. Interorbital width 3.51, diameter of eye 4.08 in snout.

Body is more rugged in general appearance than in the preceding species. Anterior

oblique margins weakly undulated from opposite of gill chamber to tip of snout, which is broadly elongated to the blunt tip. Tail stiffened, rod-like in shape (Round-type), 0.90 and 1.15 times in disc-length and disc-width, respectively. Interorbital space rather flat, the width 1.19 times as broad as the longer diameter of eye. Pelvic fin moderately notched with anterior lobe broadened. Clasper large, stiffened with blunt glans, reaching to middle of tail, whereby dermal fold originates and becomes broader rearward on both sides. Two dorsals moderately large, ensuing small caudal fin.

Entire dorsal surface setose with rather thickened prickles, which become denser toward anterior oblique marginal region, orbital margins, mid-belt of disc from nucha to tail, but become sparse toward basal portion of pectoral fins. Posterior lobe of pelvic fin and two dorsals also prickled. Nuchal thorns illegible, but shoulder one rather distinct on both sides. Backlar spines broadly developed, one to seven in a transverse series. Enlarged thorns 20, setting in a longitudinal row along mesial line of tail. (C_1 in Fig. 62).

Color of dorsum in fresh condition uniformly golden drab, which changes from brown to grayish after preservation; ventral surface white as a whole, with exceptions of tail and margin of cloaca, both of which are pigmented with dusky color.

Internal: Rostral cartilage rather feeble, anteriorly elongated into slender rod-like projection, which is shorter than cranium (C in Fig. 28). Rostral appendices moderately developed, reaching posteriorly one-third the way to the base of rostral cartilage. Anterior fontanelle tumbler-like in shape, and posterior one elongated, much constricted at midway point.

Electric organ feebly developed and electric elements not so numerous, locating on posterior portion of tail (C in Fig. 35). Vertebral counts in two portions, 32—36 + 71—76. Intestinal spiral valves 8—10, and 9.0 in average. Heart valves 3 in a row in most cases.

Clasper is of Type 5, much specialized, particularly annotated with broadly expansible glans without pseudosiphon, and much reduced dorsal terminal 1 (C in Figs. 3,4 and 12).

The external features mentioned above was derived from the holotype, but the internal features as well as the followings were taken from paratypes.

Egg-capsule: Egg-capsule of this species closely resembles in general appearance those of species B, E and F, in having long horns and rough surface. But, having examined in detail the characters, the capsule-wall of the present species was referred to Type 4 together with that of species B and E, in having numerous prickles running lengthwisely over the surface ($C_{4,5}$ in Fig. 62).

Developmental stages: Snout becomes relatively longer with growth of the fish, covering the ratio in head-length from 1.89 to 2.07 times (C in Table 6). As shown in the accompanying Figs. the snout is blunter in the young than the adult (C_{1-3} in Fig. 62). Proportional measurement of eye-diameter to snout-length and to interorbital width are remarkably changed with growth of the body, viz., the eye-diameter is greater than one-third times as long as snout, and it is longer than interorbital width in the young. Tail about as long as disc-width in young, but the former becomes shorter than the latter with the growth of the fish (C in Table 7).

Spination of dorsum almost the same throughout life, except for the adult male, in which the prickles setting on basal portions of pectoral fins much fewer than those of the adult female. Nuchal thorns one to four, if present, usually inconspicuous; a pair of shoulder thorns conspicuous in most cases; a row of 18 to 30 tail thorns

obviously developed, interrupted by intervention of lst dorsal fin.

Color on both sides of body rather same throughout life as explained in the holotype. The present species is apparently deep-sea dweller off northern part of the main island of Japan, from Chiba to Aomori Prefectures, where the present fish is captured rather numerous by means of deep-sea trawler operating in the depth of about 200 to 300 fathoms.

Remarks: The present species very closely resembles the foregoing species **B**, in general appearance, but the two are clearly distinguishable from each other by, i) clasper structure as explained elsewhere, ii) degree of development of spination, iii) proportional length of the eye-diameter to the snout-length (Table 19), iv) length of the rostral cartilage relative to cranium, and v) number of vertebrae and intestinal valves as has analyzed in foregoing description (Tables 9 and 10). Of these, proportional ratio of eye-diameter in snout-length varies from 2.10 to 5.30 times (3.45 in average) in the present species as compared with 2.26 to 4.45 times (3.26 times in average) in the foregoing species. A biometric comparison of the two species in some dimensions was tested by means of t-method as follows:

Table 19. Results of t-test for some dimensions of the two species, **B** (Y) and **C** (X); number of specimens of these fishes being respectively 34 and 24, and the degree of freedom for the test is 33 and 23, respectively. For other abbreviations, see p. 7.

Items	Mean, $\bar{X}$ / $\bar{Y}$	S	t	t_0 (α =0.05)
Ratio of snout in head	2.01/2.08	0.12	0.89	2.00
——— head in disc-l.	1.91/1.89	0.04	2.05	—
——— tail in disc-w.	1.12/1.14	0.09	1.02	—
——— ___ in total l.	1.76/1.80	0.07	1.68	—
——— eye-dia. in snout	3.65/3.26	0.71	2.04	—

On the basis of above figures, it may be said that the small differences between the two species are found in their proportional ratios of head in disc-length and of eye-diameter in snout.

Breviraja (*Bathyraja*) *abasiriensis* ISHIYAMA
(Abbreviated as **D**; Japanese name, Kitano-kasube)
Fig. 63

Breviraja abasiriensis ISHIYAMA, 1952, p. 19, fig. 9, Pl. 3, Okhotsk Sea (original description). —— 1955, p. 276, figs. 2—4, Okhotsk Sea (electric organ). —— MATSUBARA, 1955, p. 138, Okhotsk Sea (key).

Materials examined: 10 specimens (622—715 mm) including holotype, offing of Abashiri to Monbetsu, Okhotsk Sea; Oct. 1948 and May to June, 1951.

As regards this species the present author has given details in previous report (1952). Therefore, the diagnostic characters heretofore being uncertain will be mentioned below.

Internal: The clasper is of Type 5 (**D** in Figs. 3, 4 and 12), characterized by having broadly expansible glans without pseudosiphon accompanied by much reduced dorsal terminal 1. Heart valves mostly 4 in a row. Electric organ moderately developed and the elements forming the organ moderate in number. Abdominal and precaudal vertebrae 31—33 and 64—70, respectively (**D** in Figs. 43 and 44, and Table 9).

Egg-capsule: Unknown.

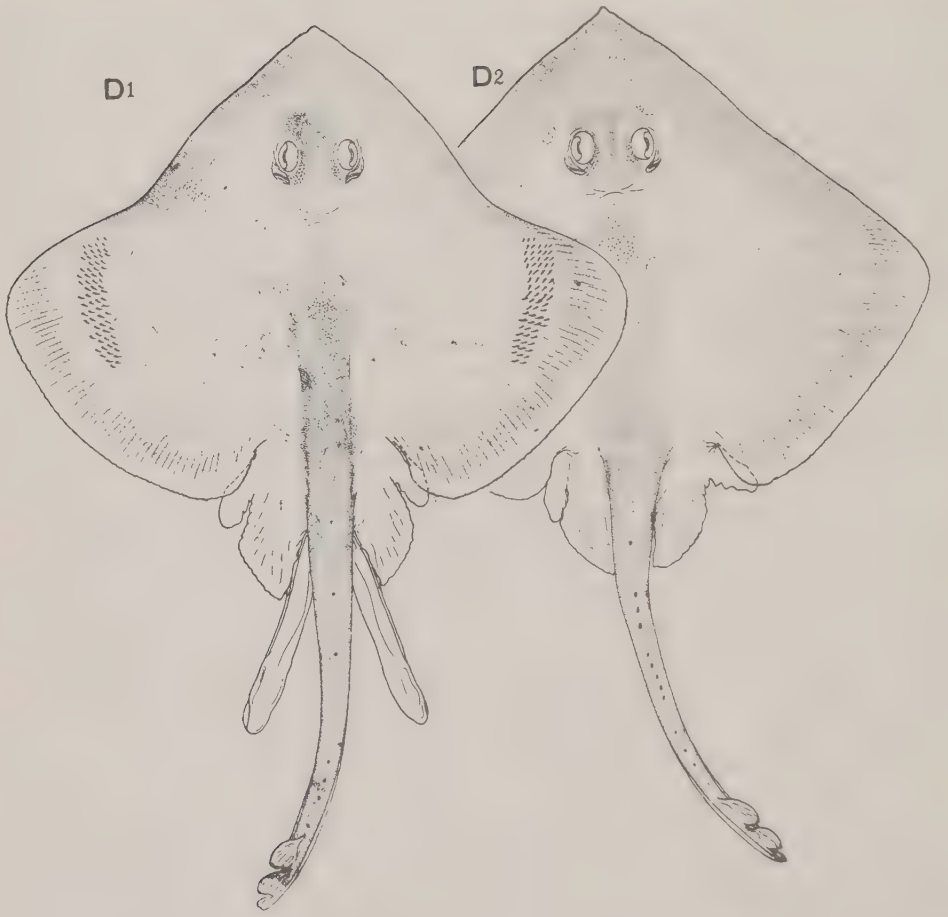

Fig. 63. *Breviraja abasiriensis* ISHIYAMA; D_1, holotype, adult male (715 mm); D_2, adult female (710 mm), from Okhotsk Sea, off Abasiri, Hokkaido.

Notes: The present species is distinct from any other relatives in the first appearance of its peculiar color patterns of the dorsum as has recorded in the previous paper (l.c.). On the basis of internal features, especially of the clasper, however, the systematic position of this species within the subgenus may be suggested to be in close relation with species **C**, through which the phyletic stem including these two species may be linked with other forms, such as species **B**.

The present species appears rather rare in the catch by the motor trawler operated in the Sea of Okhotsk and the neighbouring region.

Breviraja (*Bathyraja*) *diplotaenia* ISHIYAMA
(Abbreviated as **E**; Japanese name, Ribbon-kasube)
Fig. 64

Raja diplotaenia ISHIYAMA, 1950, p. 30, figs. 1 and 2 (egg-capsule).
Breviraja diplotaenia ISHIYAMA, 1952, p. 15, fig. 5, Pl. 2 (original description).
—— ISHIYAMA, 1955, p. 271, figs. 2—4, northern Japan (electric organ).
—— MATSUBARA, 1955, p. 138 (key).

Materials examined: 31 specimens (407—850 mm in total length) including holotype, and 5 egg-capsules, offing of Chôsi to Kushiro, the Pacific coast; Oct., 1948 and May to June, 1951.

A detail description of the present species was given in the previous article (ISHIYAMA, 1952), so that only the characteristics of internal features are given here so as to meet with keen diagnosis responsible for discrimination of the species and for interpretation of the characteristics useful for phyletic consideration within the genus.

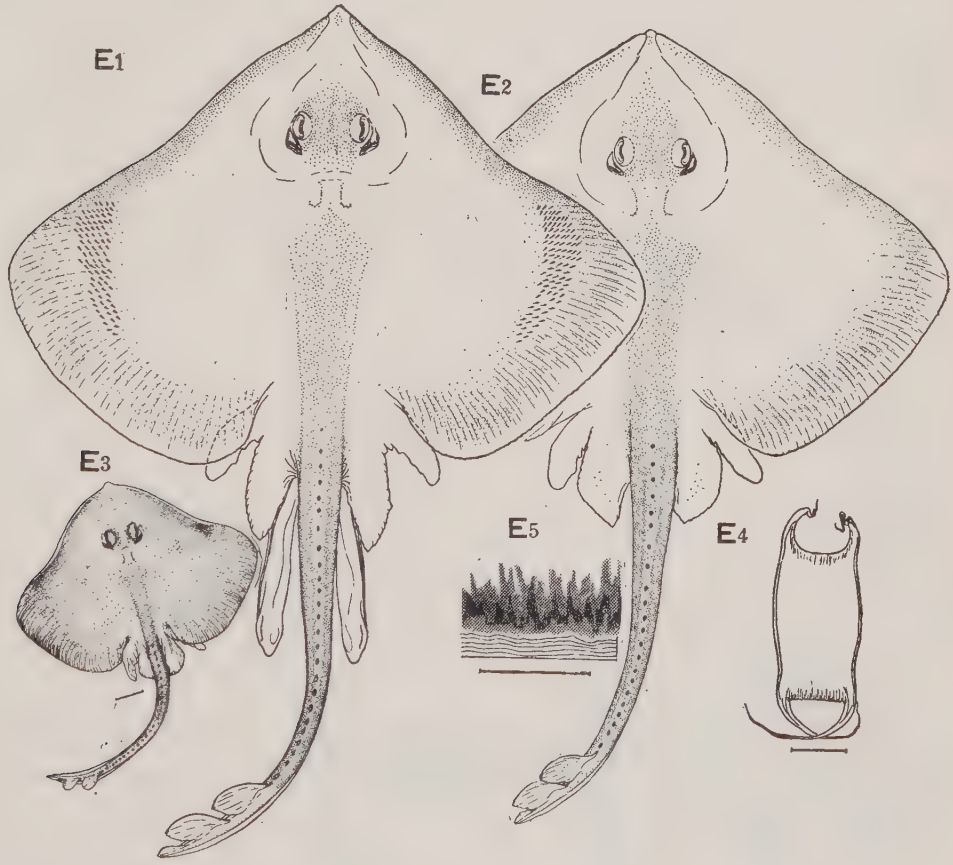

Fig. 64. *Breviraja diplotaenia* ISHIYAMA; E_1, holotype, adult male (850 mm); D_2, adult female (797 mm); D_3, young male (409 mm); D_4, egg-capsule, scale 5 cm; D_5, section of capsule-wall, scale 1 mm; off Erimo Peninsula, Hokkaido.

The clasper structure is of Type 6, which particularly attracts our attension to the possession of small pseudosiphon and broad dorsal terminal l (**E** in Figs. 3, 4 and 12). Abdominal and precaudal vertebrae, 31—37 and 70—74, respectively (**E** in Figs. 43 and 44). Heart valves 6 in a row in most cases (**E** in Table 11). Electric organ well-developed, rather large (**E** in Fig. 35).

Notes: This species is thought without doubt to be corgeneric descendant with the species **F** and **G**, in having some fundamentally important features closely related

with each other, such as number of vertebrae and clasper structure. Moreover, it may be sure to believe that the present species might be nearest representative to their suppositional common ancestor which may be closely related to species **B** in various features as aforementioned.

Breviraja (*Bathyraja*) *matsubarai* ISHIYAMA
(Abbreviated as **F**; Japanese name, Matsubara-ei)
Fig. 65

Breviraja matsubarai ISHIYAMA, 1952, p. 10, figs. 3 and 4, Pl. 1, northern Japan (original description). —— ISHIYAMA, 1955, p. 271; figs. 2—4, northern Japan (electric organ). —— MATSUBARA, 1955, p. 138, northern Japan (key).

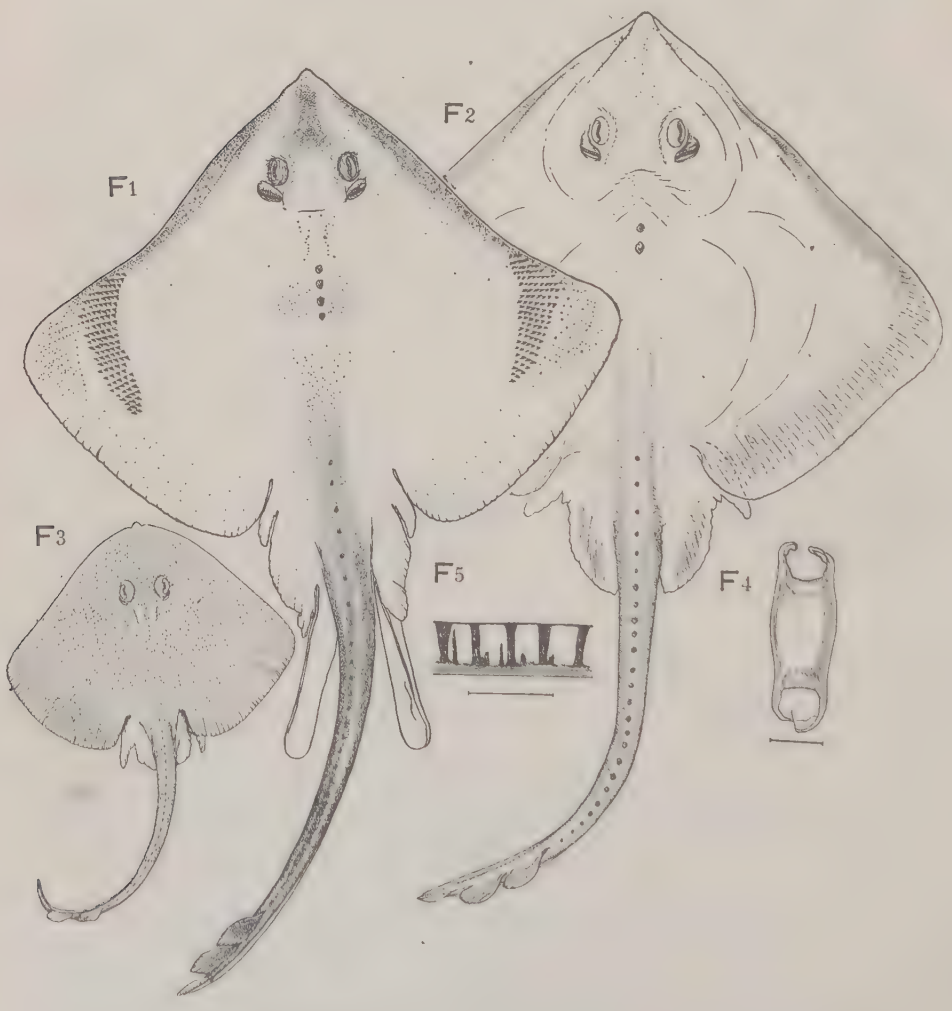

Fig. 65. *Breviraja matsubarai* ISHIYAMA; F_1, holotype, adult male (1063 mm); F_2, adult female (1105 mm); F_3, young female (202 mm); F_4, egg-capsule, scale 5 cm; F_5, section of capsule-wall, scale 1 mm; from off Erimo Peninsula, Hokkaido.

Materials examined: 18 specimens (176—1165 mm in total length) including holotype, and 2 egg-capsules, caught in the deep sea off Kushiro to Same, the Pacific coast of northern Japan; May to June, 1951.

As regards the present species the writer has given the description in detail (l.c.), so that merely some characteristics are herein appended so as to make clear the diagnosis for the basis in seeking a derivation of the species.

Structural characteristics of the clasper, Type 6, which is distinguishable from those of any other species, in having specially the distinct pseudosiphon and the partly reduced dorsal terminal 1 (**F** in Figs. 3,4 and 12), numerous precaudal vertebrae ranging from 71 to 73 (**F** in Fig. 44), and much specialized egg-capsule (**F**$_{4,5}$ in Fig. 65).

Notes: From above noteworthy features together with some other external and internal ones, there may be no doubt that the present species is the most specialized form resulted from its life in the great depth (cf. Table 1). The present species is found below 800 meters off the Pacific coast of the northern Honsyu.

Breviraja (*Bathyraja*) *aleutica* (GILBERT)
(Abbreviated as **G**; Japanese name, Alaska-kasube)
Fig. 66

Raja aleutica GILBERT, 1895, p. 397, Pl. 21, Aleutian waters (original description). —— JORDAN and EVERMANN, 1896, p. 75 (reference). —— JORDAN and GILBERT, 1899, p. 435 (reference). —— EVERMANN and GOLDSBOROUGH, 1907, p. 230, Alaska. —— SOLDATOV and LINDBERG, 1930, p. 22 (reference). —— ANDRIASHEV, 1939, p. 1 (reference). —— FOWLER, 1941, p. 393 (reference).

Raia aleutica GARMAN, 1913, p. 343 (reference).

Breviraja aleutica ISHIYAMA, 1952, p. 9, northern Japan (key). —— ISHIYAMA, 1955, p. 271, figs. 2—4, northern Japan (electric organ). —— MATSUBARA, 1955, p. 139, northern Japan (key).

Materials examined: 17 specimens, (412—1510 mm in total length), and 17 egg-capsules; deep seas off northern Honshû on the Pacific and coastal waters of Okhotsk Sea off Hokkaido; Oct., 1948 and June, 1951.

External: Disc-length 1.71—1.98 (1.90 in average), disc-width 1.49—1.71 (1.62), tail 1.75—2.20 (1.91) times into total length, respectively. Snout 1.60—2.05 (1.84) times into head, which is 1.72—1.87 (1.78) times into disc-length. Eye 4.16—8.44 (5.74), interorbital width 3.20—4.48 (3.89), 1st dorsal fin 4.70—6.97 (5.61), the second 4.83—6.61 (5.16) times into snout, respectively.

Precaudal length 1.86—2.82 (2.26) and caudal fin 5.50—11.61 (8.57) times into head, respectively.

Body largest among members of the northern form. Snout very long and flexible in touching, anterior margins of the disc almost straight even in the adult. Tail rather long and thick, almost as long as disc, but shorter than disc-width. Cutaneous fold on lateral sides of tail distinct, covering from middle to tip of tail. Pelvic fin moderately notched; two dorsals rather large, separated by a space, varying from 9.4 to 14.5 times into head-length; caudal fin well-developed, ensued from posterior end of base of 2nd dorsal fin. Clasper long, slender and stiff when matured.

Spination on dorsal surface is characteristic, viz., enlarged thorns, 34—40 (36.9 in average) in number, set in a row, running continuous from the nuchal to 2nd dorsal

fin, but interrupted by an intervention of the 1st dorsal; the one to two thorns also set on each shoulder; minute prickles covering entire dorsal surface in the young, but in the matured male the spination on the pectoral fins becomes largely sparser and the surface of the pelvic fins entirely smooth; the prickles covering sides of tail somewhat thickened; two dorsal and caudal fins also armed with prickles; backlar thorns of alar spines distinct in 24 to 25 transverse rows with 1 to 6 in one series; ventral surface of head and distal part of tail roughened with minute prickles (G_1—G_3 in Fig. 66).

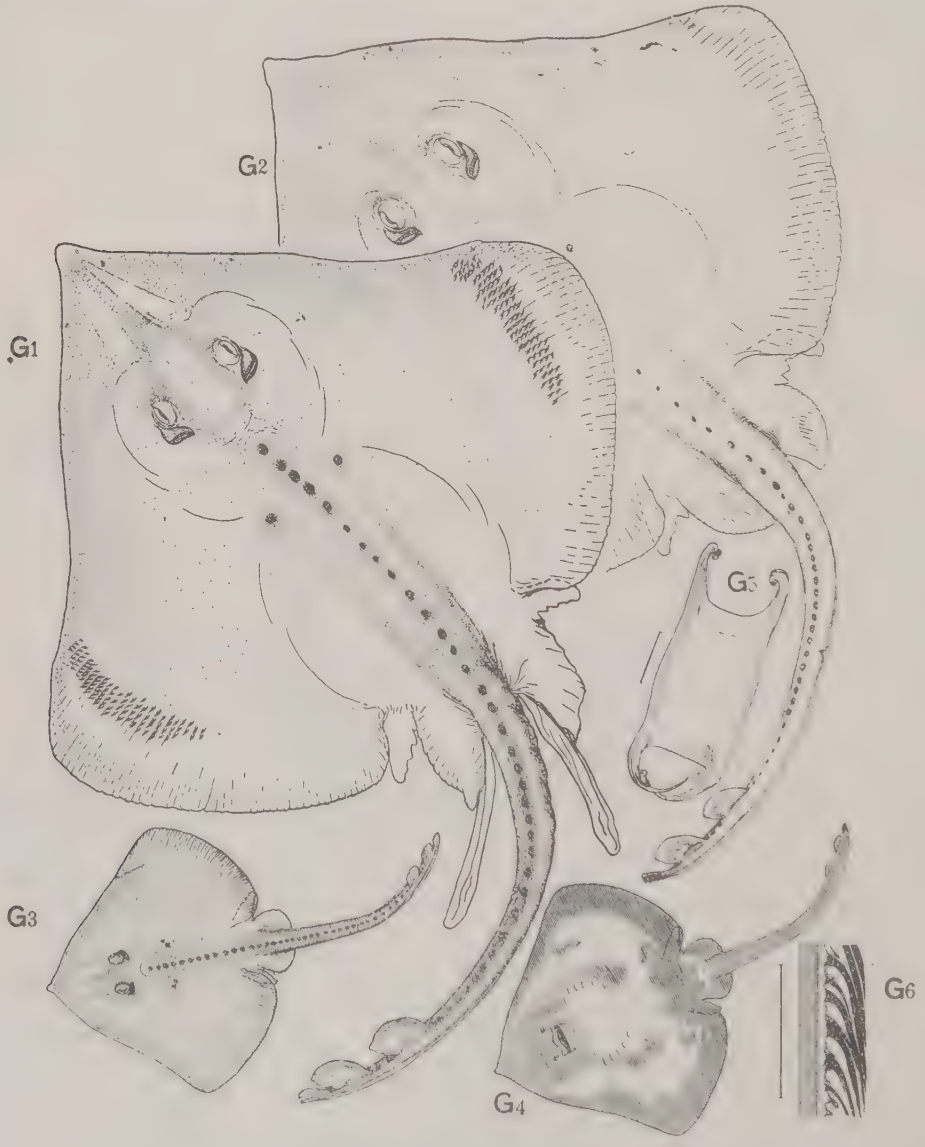

Fig. 66. *Breviraja aleutica* (GILBERT): G_1, adult male (1500 mm); G_2, adult female (1500 mm); $G_{3,4}$, young female (230 mm), showing color patterns on ventral side in G_4; G_5, egg-capsule, scale 5 mm; G_6, section of capsule-wall, scale 1 mm; from off Erimo Peninsula, Hokkaido.

Color of dorsum golden drab when fresh, but gray in preservation; ventral surface pigmented with dark blotches on such portion as; marginal portion of disc, entire surface of pelvic fins and tail, anterior half of head, and on outer side of a series of gill openings (G_4 in Fig. 66).

Internal: Rostral cartilage very long and tapers in its main portion, meandering in serpentine form, which is described elsewhere; rostral appendices rather long and distinct. Anterior fontanelle broadly opened, and the posterior one long and constricted at the middle portion (G in Fig. 28).

Vertebrae 35—38 (36.0 in average) + 69—74 (70.5) (G in Figs. 43 and 44). Electric organ moderately large runs rearward from middle to distal tip of the tail (G in Fig. 35). Intestinal valves 8—9 (8.8) (Table 10), and heart valves 4—5 in a row (G in Table 11). Clasper, Type 6, characterized especially by having pseudosiphon (Type-Ps^1) and much reduced ventral terminal (G in Fig. 3, 4 and 12).

Egg-capsule: Very large in size, measuring from 120 mm to 136 mm long exclusive of horns; entire surface of capsule roughened with minute prickles, bending anteriorly (Type 4), ($G_{5.6}$ in Fig. 66).

Notes: Scince occurrence of the present species has been first described and figured by GILBERT (1895) from the Sannak Pass, Aleutian Island, and redescribed by JORDAN and EVERMANN (1896), using the same specimen, immature male of 835 mm in total length, no one has given any information on this species, except for the present author (1952, '55, '57). By careful comparison of external features in the original description with that of the Japanese specimens here dealt with, the present author has found that they agree rather well each other, especially in the general spination and coloration, in number and arrangement of the enlarged thorns setting along the mesial line of dorsum and tail, and in the relative lengths of both snout and tail. Nevertheless, there are some doubts for the identification of the present specimens inasmuch as these external features mentioned above reveal rather extensive variations in our specimens in accordance with growth of the fish. Such uncertainty in the identification of our specimens on the basis of the external features may be ascribed to the incompleteness of the examination of the internal features of the holotype.

Until we have more accurate knowledge of the such features which seem to be important for the classification of the rajids, it appears to me appropriate, for the present, to assign the Japanese species to the Aleutians *aleutica* with which they are in agreement in some external features as mentioned above.

The geographical distribution of the present species appears rather great, if the view mentioned above is correct, covering the deep sea from off northern Japan to the Aleutians through the Sea of Okhotsk (Fig. 1). If this opinion is justifiable on the habitat range, it is an interesting fact to note here that the Japanese rajids have close affinity to those inhabiting the Aleutian and Alaskan waters through the so-called northern members like the present species.

Arctoraja, n. subg.

Dorsum almost smooth, with exceptions of anterior marginal portion, orbital region, mid-belt and tail regions, where the body is furnished more or less extent with broad stellate prickles. Ventral side entirely smooth. Snout moderately elongated with blunt tip, the anterior portion easily be bent. Tail rather short, flattened dorso-ventrally (Depressed-type), much shorter than width of disc, measuring as long as

70% or more shorter than width. Both dorsal and pelvic fins moderately large; caudal fin much reduced in size.

Rostral cartilage slender, rather flat, more or less meandered in most cases when dissected the preserved specimens; rostral appendices small, reduced into less than one-third length of rostral cartilage. Anterior fontanelle large, but posterior one elongated with a constriction at the midway portion.

Vertebrae more numerous than in any other subgenera of the present genus, covering respectively 35--40 in abdominal and 82—88 in precaudal portions. Intestinal spiral valve also numerous, varying from 11 to 13.

Clasper is of Type 7, especially being noticed in the absence of pseudosiphon and in having specialized axial cartilage and dorsal terminal 1. Electric organ developed in large size with numerous electric elements.

Egg-capsule peculiar in shape and configuration of the surface (Type 2).

Type species: *Raja smirnovi* SOLDATOV et PAVLENKO

Notes: The present subgenus is distinguishable from all other relatives among the genus, in having much shorter tail armed with large electric organ, numerous counts of both precaudal vertebrae and intestinal valves, and also peculiar egg-capsule which are thought to be credible for erection of the present new subgenus. The present subgenus is referred to one species and two subspecies, the latter of which are newly established herein.

Key to species and subspecies of the subgenus *Arctoraja*

1a. Enlarged thorns setting continuous in a row running along mesial line from the nuchal to dorsal fins; a pair of the thorns developed on each shoulder. Width of disc less than 1.5 times of tail. Rostral appendices longer than one-third the length of rostral cartilage (H in Fig. 28). Precaudal vertebrae 82. Ridge and funnel of glans clasper well-developed; dorsal lobe of the glans without prickles. Tubercles on surface of egg-capsule densely developed with ridged apexes ..... *parmifera* (Fig. 67)

1b. Two to four enlarged thorns setting in a row on the nuchal, isolated from those of caudal ones; one large thorn developed on each shoulder. Width of disc greater than 1.5 times the length of tail, except for the young. Rostral appendices shorter than one-third the length of rostral cartilage (Fig. 28: I, I′). Precaudal vertebrae 83 to 91. Ridge and funnel of glans clasper obscure or absent; dorsal lobe of the glans furnished with prickles. Tubercles growing on egg-capsule sparsely developed with domed apexes.

2a. Tail 1.1 to 1.2 times as long as disc-width, and 1.4 to 1.7 times the length of head, in most cases. Caudal fin usually more distinct, and electric organ less developed than 2b (I in Figs. 35 and 38) ..... *smirnovi smirnovi* (Fig. 68)

2b. Tail 1.2 to 1.3 times as long as disc-width, and 1.3 to 1.5 times the length of head, in most cases. Caudal fin usually reduced to very small flap, and electric organ well-developed (I′ in Fig. 38) ..... *smirnovi ankasube*, n. subsp. (Fig. 69)

Breviraja (*Arctoraja*) *parmifera* (BEAN)

(Abbreviated as H; Japanese name, Tsuno-kasube)

Fig. 67

Raia parmifera BEAN, 1882, p. 150, Iliuliuk, Unalaska (original description). —— JORDAN and GILBERT, 1883, p. 378 (copied). —— GARMAN, 1913, p. 345 (compiled).

Raja parmifera GILBERT, 1895, p. 395, Bristol Bay, Alaska. —— JORDAN and EVERMANN, 1896, p. 74 (copied). —— JORDAN and GILBERT, 1899, p. 434, Bering Sea. —— EVERMANN and GOLDSBOROUGH, 1907, p. 230, Alaska. —— SOLDATOV and LINDBERG, 1930, p. 21 (reference). —— TARANETZ, 1935, p. 90 (reference). —— FOWLER, 1941, p. 394 (reference). —— ISHIYAMA, 1950, p. 30, figs. 1 and 2, Hokkaido (egg-capsule).

Breviraja parmifera ISHIYAMA, 1952, p. 1, Hokkaido (key). —— 1955, p. 16, fig. 4 (electric organ). —— MATSUBARA, 1955, p. 138 (key). —— ? KOBAYASHI and UENO, 1956, p. 240, fig. 2, Bristol Bay.

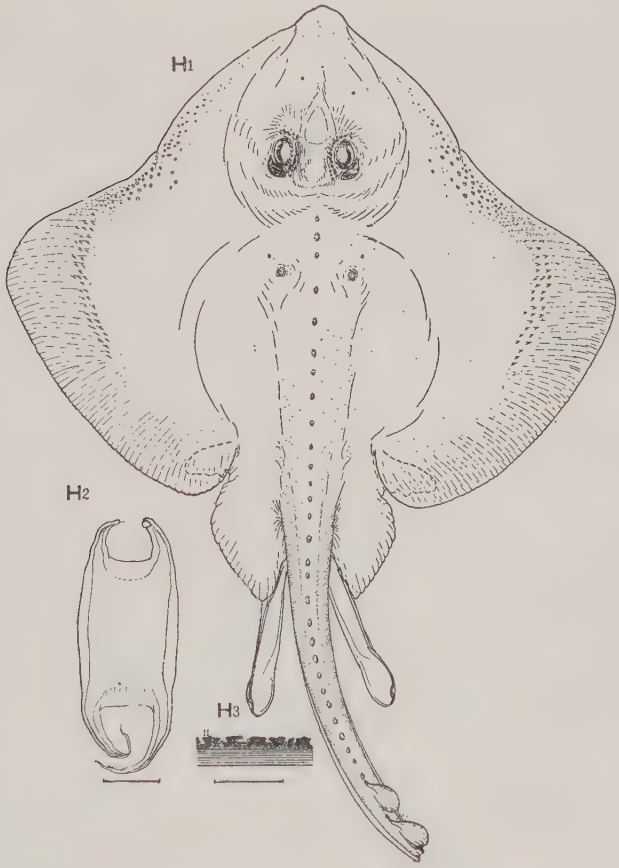

Fig. 67. *Breviraja parmifera* (BEAN): H_1, adult male (941 mm); H_2, egg-capsule, scale 5 mm; H_3, section of capsule-wall, scale 1 mm; from off Muroran, Hokkaido.

Material examined: 1 specimen, adult male of 941 mm in total length, and 2 egg-capsules, collected by Dr. MATSUBARA from off Muroran, Hokkaido, in 1938.

External: Disc-length 1.79, disc-width 1.45 and tail 2.14 in total length; head 1.86, snout 3.79 and precaudal 1.33 in disc-length; interorbital width 3.51, eye-

diameter 5.27, 1st and 2nd dorsal fins 2.85 in snout.

Anterior oblique margin of disc undulated, bearing a shallow notch at the middle way, which may seems to have caused by an accident. Snout very soft and broadly elongated with blunt tip. Eye moderately large, slightly less than interorbital width, which is shallowly concave. Tail rather short, depressed dorso-ventrally, about two thirds times as long as disc-width, and 1.61 times as long as head; precaudal portion longer than three times the length of procaudal one. Pelvic fin normally notched; clasper long and thickened posteriorly, extends beyond middle of tail; two dorsals rather small, subequal in size, separated by a space equal to about half the basal length of dorsal fin; caudal fin very small but distinct, reduced into small flap about half times as long as dorsal fin.

Body largely smooth on dorsal surface, but marginal and central portions of disc, supraorbital and tail are armed more or less with prickles or thorns as: a few prickles scattering on snout, rather thickened ones covering anterior marginal portion; very small ones on posterior oblique margins of disc; somewhat thickened scales on supraorbital ridge; very large thorns, numbering 30, in a continuous row from nucha to dorsals; a pair of the thorns on each shoulder; mid-belt rearward from the center of disc furnished with numerous prickles, which are connected with those developed on tail. Two dorsals also setose but pelvic fin and under surface of body entirely smooth.

In preserved specimen dorsal side uniformly brown, under surface white, with exception of marginal portion of cloaca, where the skin is pigmented with dusky (Fig. 67).

Internal: Rostral cartilage very feeble, elongated, and rod-like in shape as in case of other members of this genus; rostral appendices rather long (H in Fig. 28). Vertebrae 39 + 82. Intestinal valves 12 (Table 10); heart valves 4 to 5 in a row (H in Table 11).

Clasper, Type 7, characterized by having incomplete pseudosiphon developed on inside border of the glans, ridge and funnel as external elements and broad dorsal terminal 1 and accessory terminal as internal elements (H in Figs. 3, 4 and 13).

Egg-capsule: A pair of the egg-capsules was examined that are distinguished from those of other members in the following points; i) surface rather rough, furnished with minute tubercles running lengthwise series with ridged appexes, ii) horn rather long and flattened, continuous with rather broad keel on each lateral side ($H_{2,3}$ in Fig. 67).

Notes: Descriptions given above were based on a matured male, so the variations of both external and internal features are uncertain. But the feature of male organ, vertebral counts, and configuration of the egg-capsule suggest that this species is referable to the present subgenus.

Since BEAN has first recorded the present species in 1882 from the Alaskan water several authorities have reported the same species from the same region. The single Japanese specimen here dealt with agree rather well with the holotype in figure and description in various features except for having blunt snout and an unreliable incision on antero-lateral margins of disc. Quite recently, KOBAYASHI and UENO (1656) gave a detailed description and a fine figure under the name of this species based on some specimens taken from the Bristol Bay, Alaska. These specimens also agree rather well with the holotype in description, but differs from our present specimen at least in having pointed snout and in lacking an incision on antero-lateral margins

of the disc. But, because of lacking of the precise description on the holotype the present author can not be sure at present whether or not the present Japanese specimen is identical with the present species, and again whether or not the identification given by KOBAYASHI and UENO is correct*). At any rate, it may be meaningful for zoogeography that the northern North Pacific is inhabited by rajid fishes which are closely related to those found in the waters off Hokkaido.

Breviraja (*Arctoraja*) *smirnovi smirnovi* (SOLDATOV et PAVLENKO)
(Abbreviated as I; Japanse name, Dobu-kasube)
Fig. 68

Raja smirnovi SOLDATOV et PAVLENKO, 1915, p. 162, Pl. 5, Peter the Great Bay (original description). —— SOLDATOV et LINDBERG, 1930, p. 21, Pl. 1, Peter the Great Bay; —— TARANETZ, 1935, p. 90 (note). —— FOWLER, 1941, p. 369 (reference). —— SCHMIDT, 1950, p. 33, Okhotsk Sea.

Raja binoculata SCHMIDT, 1904, p. 291, Okhotsk Sea. —— FOWLER, 1930, p. 502 (reference).

Breviraja smirnovi ISHIYAMA, 1952, p. 8, Sea of Japan; Okhotsk Sea (key). —— 1955, p. 271, Okhotsk Sea (electric organ). —— MATSUBARA, 1955, p. 138 (key).

Materials examined: 21 specimens, 354—1160 mm in total length, and 4 egg-capsules; Okhotsk Sea, off Wakkanai and Monbetsu, Hokkaido; Oct., 1948 and June, 1951.

External: Disc-length 1.69—1.83, disc-width 1.25—1.43 and tail 2.03—2.38 in total length; head 1.83—1.97 and snout 2.92—4.44 in disc-length; interorbital width 2.80—4.01 and eye-diameter 1.42—1.72 in snout, respectively.

Body very swollen with flexible snout and pectoral fins when fresh. Disc broad, much wider than long, the length is measured from 70 to 80% of the width. Tail relatively short, depressed dorso-ventrally, about half times as long as total length (Table 7); precaudal length about half the width of disc, ranging from 1.86 to 2.32 times in the latter, and the procaudal reduced to about one-third length of precaudal; integumentary folds along sides of tail distinct posteriorly, originating at the middle between the root and tip of tail. Interorbital space flat, apparently wider than eye-diameter in the adult, but equal to the latter in the young specimen measuring about 400 mm in total length. Pelvic fins notched in moderate degree with rather broad anterior lobe; two dorsals rather small, subequal in size, about twice as long as eye-diameter; caudal fin reduced into about half length of the 1st dorsal measured in oblique. Clasper very large, stiffened when matured, the posterior extremity blunt, reaching beyond middle of tail.

Dorsum of disc almost smooth in adult, except for marginal, supraorbital and central regions, where either prickles or enlarged thorns or both of them are developed with more or less stellate bases. While, in young the dorsal entirely setose, although sparsely prickled on central portion of disc and on interorbital space as in the case of other northern members. Two to four enlarged thorns setting on the nuchal, and one on each shoulder; tail densely covered with prickles, which extend anteriorly to the center of disc, forming a distinct mid-belt although the prickles gradually decreasing anteriorly; tail also armed with a row of 20 to 34 thorns ar-

* A comparison of the rajids between the two sides of the northern North Pacific will make clear this question.

ranged regularly along mesial line, but interrupted by an intervention of first dorsal fin. Two dorsals sparsely prickled, but the pelvic and caudal fins naked.

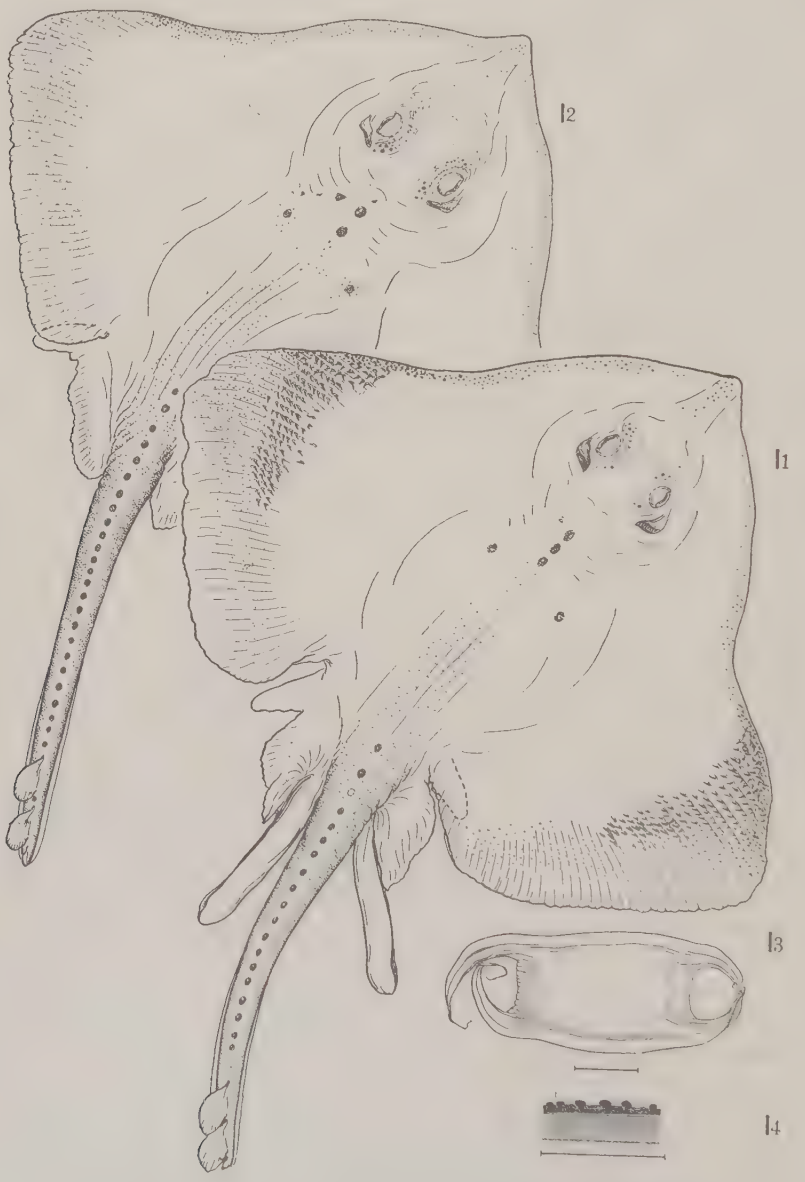

Fig. 68. *Breviraja smirnovi smirnovi* (SOLDATOV et PAVLENKO); I_1, adult male (970 mm); I_2, adult female (1052 mm); I_3, egg-capsule, scale 5 cm; I_4, section of capsule-wall, scale 1 mm; from the Okhotsk Sea, off Monbetsu, Hokkaido.

Mature male remarkably armed with 26 to 27 transverse series of alar spines, each series represented by 1 to 7 spines. It should be remembered herewith that the outer margin of dorsal lobe of the glans clasper furnished sparsely with minute

prickles as has mentioned elsewhere. The ventral surface of body entirely smooth.

Prior to preservation in formalin, the dorsum golden drab without any pattern, but it changes brownish gray after preservation; the ventral surface whitish except for marginal portion of cloaca and whole of the tail, both of which more or less pigmented with dusky extent. (Fig. 69 $I_{1,2}$).

Internal: Rostral cartilage very feeble; rostral appendices very small, shorter than one-third the length of the cranium; anterior fontanelle broad, shifted towards the center of cranium; posterior fontanelle long, constricted at the central portion (**I** in Fig. 28).

Vertebrae more numerous than in any of the present genus in the northern members, ranging from 35 to 40 and from 83 to 88 in abdominal and precaudal portions, respectively (**I** in Figs. 43 and 44). Intestinal valves also numerous, covering from 11 to 13, (Table 10); heart valves 4 to 5 in a row, in most cases (**I** in Fig. 51; Table 11).

Electric organ larger than in any of the northern members, excepting the following subspecies, (**I** in Fig. 35). Clasper, Type 7, characterized by having prickles, much reduced pseudosiphon (Type-Ps^3) shifted to inside boader of the glans, distally truncated axial cartilage and broad dorsal terminal 1 (**I** in Figs. 4, 5 and 13).

Egg-capsule: In general shape the capsule closely resembles that of the preceding species (**H**), in having flattened horns with slender tips, broad lateral keels and rather rough surface. But it is distinguishable from the latter in minute structure developed over the surface, viz., very small tubercles setting lengthwisely are furnished sparsely with domed appexes ($I_{3,4}$ in Fig. 68).

Notes: *Raja smirnovi* recorded by JORDAN and HUBBS (1925), and by FANG and WANG (1932) undoubtedly referable to *Raja pulchra*. The former apparently differs from the latter in having at least such external features as; i) pectoral ocellus is absent (present in *pulchra*), ii) dorsum of the disc is largely smooth except for anterior margin where the disc is roughened with prickles even in the young (entirely smooth in the young of *pulchra*), iii) spines set on orbital rim are numerous in the young (three distinct spines are set on definite positions in the young of *pulchra*), iv) 20 to 34 enlarged thorns set in a single series are present on the tail (7 to 9 in the young of *pulchra*, but five rows in adult female), and v) integumentary fold on each lateral side of the tail falls at a position far from the base of tail (extends to the base of tail in *pulchra*), (cf. Figs. 83 and 84: **U**). An examination of the specimens of *Raja smirnovi* of SATO and KOBAYASHI (1956), taken from the Volcano Bay, south of Hokkaido near Hakodate has been proved that they are apparently identical with *Raja pulchra*. A comparison of their internal features, such as rostral cartilage, structures of the glans clasper and of the electric organ, and counts of the vertebrae, shows us that the two species should be referred each other to different genus as mentioned elsewhere.

Breviraja (*Arctoraja*) *smirnovi ankasube*, n. subsp.
(abbreviated as **I′**; new Japanese name, An-kasube)
Fig. 69

Breviraja smirnovi ISHIYAMA, 1952, p. 8 (pars), Sea of Japan (key). —— ISHIYAMA, 1955, p. 271 (pars), Wakasa Bay, Kyoto Prefecture (electric organ). —— HONMA, 1955[a], p. 45, off Sado Island, Niigata Prefecture. —— HONMA, 1955[b], p. 223, off Sado Island.

Materials described: Holotype, 930 mm, Wakasa Bay, off Maizuru, Kyoto

Prefecture; Oct. 13, 1953; paratypes, 24 specimens, 223—983 mm, Akita; Sado Island, Niigata Prefecture; Maizuru; Oki Island, Shimane Prefecture.

External: Disc-length 1.73, disc-width 1.29 and tail 2.31 in total length; head 1.78, snout 4.12, precaudal 1.70 and procaudal 6.14 in disc-length, respectively. Eye diameter 2.95 and interorbital width 4.04 in snout. Lengths of 1st and 2nd dorsal fins 5.12 and 5.35, and caudal fin 21.43 in head, respectively.

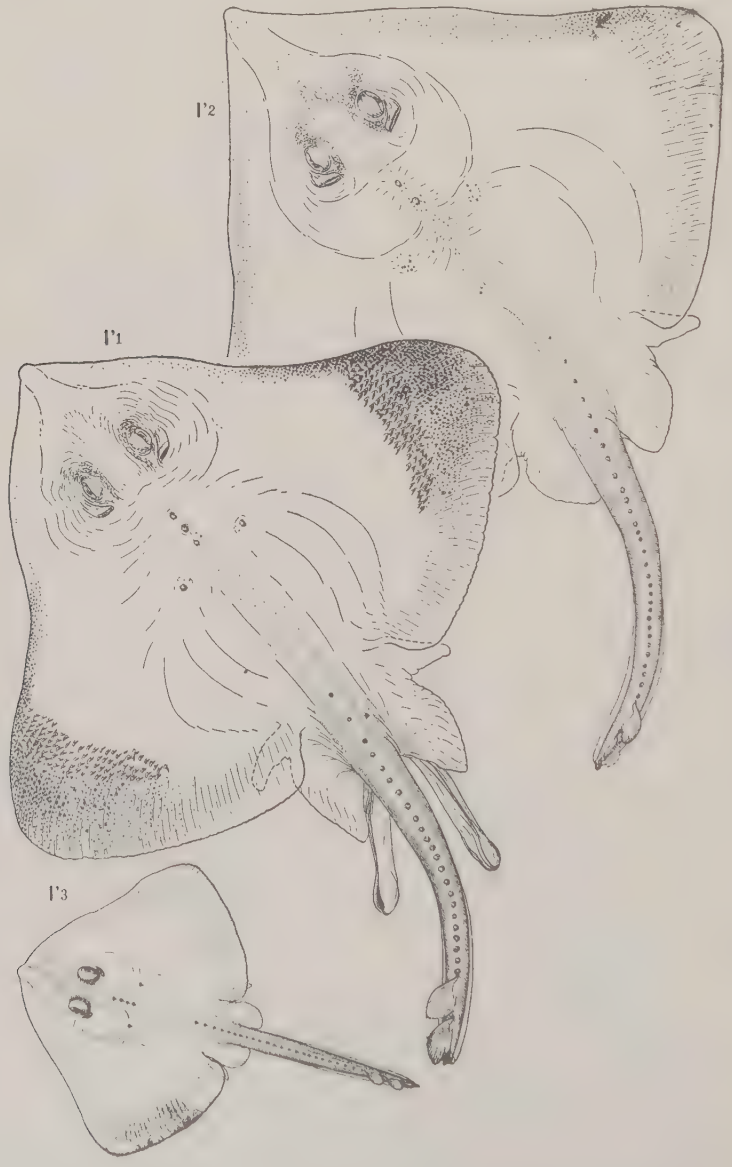

Fig. 69. *Breviraja smirnovi ankasube*, n. subsp.; I'$_1$, adult male, holotype (930 mm); I'$_2$, adult female (983 mm); I'$_3$, young male (223 mm); from off Maizuru, the Japan Sea.

General physiognomy of the present subspecies is quite similar to that of the preceding, but the two are distinguishable from each other in some external features, such as proportional lengths of the tail and of the snout, which will be mentioned in detail later on.

Internal: Of what seems to be annotated in the internal features examined in this subspecies, the characteristics revealed in the male organ and in the degree of development of the electric organ are specially noticed to show the distinction of the present subspecies from the preceding one, i.e. both the ventral and accessory terminals of the clasper of the present form is slenderer than those of the preceding (I′ in Figs. 3, 4 and 13), and the degree of the development of electric organ is more advanced in this subspecies than in the other (I′ in Fig. 38).

Egg-capsule: Uncertain.

Trend of intrasubspecific variation in the proportional ratios of both snout and tail is much similar to that of the preceding one.

Geographical distribution of the present subspecies seems to be limited to the Sea of Japan, covering from off Oki Island, Shimane Prefecture to the northern region of the sea probablly near Teuri Island, south of Wakkanai, Hokkaido, but no example was found to exist on the Pacific shelf of Japan.

Remarks: The present subspecies much resembles the foregoing one in general appearance, but the two are discriminable from each other with their internal characters as mentioned above and also with the following external ones treated biometrically.

Table 20. Result of t-test for some dimensional characters of the two subspecies, I(X) and I′(Y) number of specimens of these animals being respectively 21 and 24, and the dgree of freedom for the test, therefore, is 20 and 23, respectively. For other abbreviations, see p. 196.

Items	Mean, $\bar{X}$ / $\bar{Y}$	S	t	t_0 (α =0.01)
Ratio of snout in disc-l.	3.82 / 3.64	2.14	9.29	2.69
——— tail in disc-w.	1.58 / 1.64	0.09	8.99	—
——— ——— in total l.	2.13 / 2.15	0.10	0.66	—
——— ——— in disc-l.	1.21 / 1.25	0.07	1.86	—
——— head in tail	1.56 / 1.45	0.36	0.01	—
——— snout in head	2.05 / 2.01	0.12	1.09	—

As a result, it may be safely said from the above table that the differences between the two subspecies are significant in their proportional ratios of snout and tail. Namely, the proportions of the two bodily parts of the present subspecies are relatively smaller in regard to width or length of the disc than those of the relative.

Though there are some intricate problems concerning the nomenclatorial consideration on subspecies, and though there is no definite lower limit to subspecies category at present, as has recently been discussed by WILSON and BROWN (1953), the present writer has established the two subspecies on the basis of the facts as aforementioned.

Rhinoraja ISHIYAMA, 1952, emend

Rhinoraja ISHIYAMA, Jour. Shimonoseki Coll., Fish., 2 (1), p. 24. Genotype: *Raja kujiensis* TANAKA, 1916, off Kuji, Ibaragi Prefecture.

The diagnosis of this genus was given by the present author in his previous work

(1952), where the present genus was established. In addition to the diagnosis already given some features, which seem to be worthy for the criterion of the genus, are here newly attended by the following: Entire dorsal surface more or less studded with prickles even in the adult without remarkable reduction of the spination. Snout very soft, flexible in touching. Tail very long, slender, longer than disc. Rostral cartilage very feeble, projecting foreward with slender rod-like bar, which bears a segment on the basal portion; rostral appendices inserted before the rostral cartilage as is the case with the preceding genus. Clasper cylindrical in general shape, characterized by having a distinct pseudosiphon along dorsal border of the glans; pseudosiphon intimately lined internally with well-developed dorsal terminal 1 (Figs. 2 and 3). Abdominal and precaudal vertebrae numerous, ranging respectively 30—38 and 74—91. Turns of intestinal valves 8—10. Electric organ very small or inconspicuous, composed of cup-formed elements characteristic to the northern form. Egg-capsule with rather smooth or thorny surface, provided with slender horn at each corner.

Notes: In comparing above diagnosis with those given in the genus *Breviraja*, the present genus is distinguishable from the latter in the following points: i) relatively longer tail with more numerous precaudal vertebrae, ii) presence of rostral segment, and iii) clasper with seemingly generalized structure bearing distinct pseudosiphon.

Although it may be sure to believe that the present genus might be an offshoot sprung from an ancestor not very unlike the genus *Breviraja* as has been discussed by the author (1952), some of the characteristics given above to discriminate the present genus appear to be more specialized than the corresponding features found in the preceding genus.

Three distinct species are referable to the present genus, and they are all endemic to the deep sea along the Pacific coast of Japan from middle part to northern region of our main island.

Key to species of the genus *Rhinoraja*

1a. Dorsal surface entirely covered with more or less distinct numerous prickles without enlarged thorn on shoulder region; nuchal spines absent or present, not continuous, if present, with those on tail. Ventral side white, without any distinct color pattern. Tail almost as long as or longer than width of disc in adult. Clasper is of Type 2.

2a. Both nuchal and shoulder spines absent. Dorsal side yellowish brown in ground color, furnished with numerous dark brown spots and a pair of pectoral ocelli margined with white. Precaudal as long as or trifle shorter than, disc. Precaudal vertebrae 85—91. Ventral terminal of clasper is of Type Vt^2 .... *odai*, n. sp. (Fig. 70; Pl. I, J)

2b. 1 to 4 nuchal spines present. Dorsal side purplish gray or dark gray in basic color, furnished with darkish brown patterns or spots, but bearing no pectoral ocellus. Precaudal always longer than disc. Precaudal vertebrae 74—80. Ventral terminal of clasper is of Type Vt^1 ..... *longicauda* (Fig. 72)

1b. Dorsal surface entirely covered with numerous minute prickles accompanying enlarged thorns on shoulder and nucha; nuchal thorns continuous with those developed on tail, running in a row. Ventral side scattered with some indefinite black blotches. Tail shorter than width of disc in adult. Clasper is of Type 1, characterized by

having unique features of dorsal terminal 1 and ventral terminal without knife .... *kujiensis* (Fig. 71)

Rhinoraja odai, n. sp.
(Abbreviated as J; Japanese name, Oda-ei)
Fig. 70; Pl. I, J

Materials described: Holotype, 514 mm, off Izu Peninsula, Shizuoka Prefecture, March, 8, 1956; Paratypes, 16 specimens, 267—520 mm; 2 egg-capsules, Miya fish market, Aichi Prefecture, March—May, 1956.

External: Disc-length 2.14, disc-width and tail 1.74 in total length; head 2.42, snout 6.16; precaudal and procaudal lengths 1.19 and 6.42, in disc-width, respectively. Diameter of eye 2.18, interorbital space 2.82 in snout. Longer axes of 1st and 2nd dorsal fins 4.88 and caudal fin 11.11 in head.

Body trumped with conspicuous hue and well-armed spination. Anterior oblique margins run to blunt tip with gentle curve. Snout very short, thin and flexible in fresh, about a fifth times as long as disc-length. Eye very large, the longer axis always longer than interorbital width. Tail stout, more or less depressed in anterior portion, just as long as disc-width. Precaudal trifle longer than disc or than twice the length of head, but the procaudal is rather short, about as long as snout. Ventral fin moderately notched with rather broad anterior lobe. Two dorsals closed together without interspace between them, followed by a small flap of caudal fin. Clasper slender, quite masculinized with hard axis.

Body entirely furnished with numerous prickles without enlarged thorn on both nuchal and shoulder regions, but somewhat thickened ones covering supraorbital ridge and mid-belt of disc. Tail densely crowed with prickles accompanying a row of slightly enlarged grayish colored thorns along mesial line. Posterior lobe of pelvic fin, two dorsals and caudal fins more or less prickled. Ventral side wholly smooth, without scales.

Dorsum with yellowish to brown hue, scattered with numerous deep brown spots as large as pupil and marked with a pair of pectoral white ocelli on each side. Ventral side colorless, except for tail which bearing dusky striae of faint gray (Fig. 70 and Pl. I, J).

Internal: Rostral cartilage very slender, about as long as cranium, with a basal segment. Rostral appendices very thin, about a third as long as rostral cartilage. Anterior fontanelle broadly opened with anterior tip pointed; posterior one long, constricted at the midway point (Eig. 28 J). Abdominal vertebrae 33 to 36, the precaudal one more numerous, covering 85 to 91 (88.4 in average). Intestinal valves 8 to 10, and heart valves 4 or 5. Clasper peculiar in structure in having knife and pseudosiphon in addition to more or less well-developed dorsal and ventral terminals, based on these characteristics the organ is referred to Type 2 together with that of species **L.** (J in Figs. 3, 4 and 13). Electric organ moderately large, composed of cup-formed elements as is the case with other northern members (J in Fig. 35).

The description given above was based on external features of the holotype and on internal ones of the paratypes as well. The followings are prepared so as to give more details on external as well as internal and other characters worthy for distinguishing the present species from other relatives.

Egg-capsule: A pair of the capsule was extruded from a female measuring 502 mm in total length, captured offing of Izu Peninsula, where the depth was measured

from 330 to 350 meters. The capsule closely resembles that of species L, in having slender horns with long slits, and in having rather smooth surface (J_3, J_4 in Fig. 70). But the two are distinguishable from each other on; i) width of the capsule of the present species measuring 33 mm instead of being 43 to 44 mm in the species L, although the length exclusive of both anterior and posterior horns is subequal in the two, and ii) minute prickles covering the surface of the capsule in this species are somewhat sparser and shorter than those in species L (vide, Figs. 70 J_4 and 71 L_4).

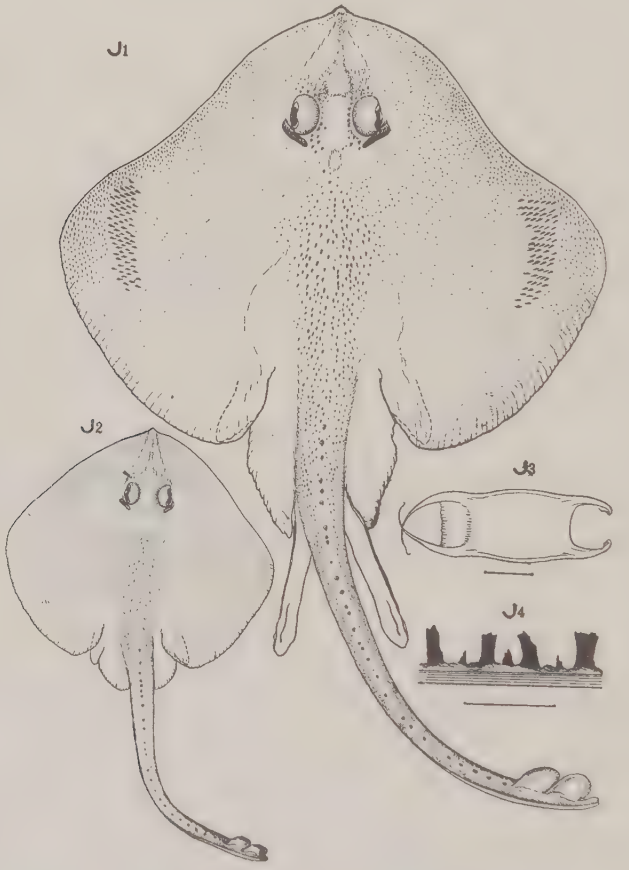

Fig. 70. *Rhinoraja odai*, n. sp.; J_1, holotype, adult male (514 mm), color patterns c.f. Pl. I; J_2, subadult female (267 mm); J_3, egg-capsule, scale 5 cm; J_4, section of capsule-wall, scale 1 mm; from near Mikomoto Island, off Izu Peninsula.

The proportional length of snout in this fish advanced than the adolescent, shorter in male than that in female, being the ratio against the head-length is 2.23 to 2.61 times in male and 2.10 to 2.20 times in female (J in Fig. 24 and Table 6). But the length of tail runs almot proportionally with equimultiple trend in both sexes (J in Fig. 31 and Table 7).

Variation in number of thorns along mesial line of tail very large, measuring 8 to 21, the reduction is thought to be due to retrogression accompanied by the develop-

ment of electric organ (cf. Fig. 35 J). Although the specimens of very young stage are not available in this study the feature of spination throughout the developmental stage may not be so much different from that found in the holotype and paratypes. But, the color and pattern of dorsum reveal intraspecific variation to some extent even in the specimens older than that of adolescent stage. Some have much distinct pectoral ocellus and brownish spots, which are more or less obsolete in others.

Remarks: The present species resembles externally *Rhinoraja longicauda* on one hand, and *Breviraja tobitukai* on the other, in having the following features; i) relatively short snout, ii) extraordinarily long tail, iii) very large eye, iv) uniformly developed prickles without noticeable specialization, and v) medium size even in the adult. But, the internal features, such as rostral cartilage, vertebral counts and clasper structure, give clear criterion for generic as well as specific significance. Namely, on the basis of both the rostral cartilage and vertebral counts, it is clear that there exist no room for doubt in separating species **A** from **J** and **L**, and that the features should be used in determining objective standard for the separation of genus. Furthermore, the present species is distinct from species **L** as shown in following lines:

Characteristics	*longicauda*	*odai*
1. Nuchal spines	present (1—4)	absent
2. Color pattern on dorsum	absent or obscure, if present	distinctly present
3. Precaudal length	as long as or shorter than disc-length	longer than disc-length
4. Precaudal vertebrae	74—80	85—91
5. Ventral terminal of clasper	Type Vt^4	Type Vt^2
6. Width of egg-capsule	43—44 mm	33 mm

It must be recorded herewith that the both the present species and species **A** were found to exist in the same region offing of Izu Peninsula, as mentioned above, although they are distinctly distinguished from each other in some fundamental features.

It is interesting to note further that the present species shows externally close resemblance to *Breviraja colesi* recorded as the type of the genus *Breviraja* taken from off the north and south coasts of Cuba by BIGELOW and SCHROEDER. In fact the two species have in common with many external features, such as short snout, large eye, relatively long tail and numerous prickles, in addition to the numerous color patterns of irregular spots and blotches of darker brown. The present writer, however, has stressed only in these internal features which are credible for the critical separation of the pressent genus from the genus *Breviraja*, and moreover, these external features mentioned above which are closely relating within the two forms are thought to be used as specific ones rather than generic. As a matter of fact, the establishment of the genus *Breviraja* has been given by the original authors being used roentogenogram of the rostrum without confirmination by dissection of the specimens*). Such being the case, as the present author has stated (1952, p. 2), there seems to meet with some doubt to confirm with either view, as a matter of stand, whether *colesi* has the rostral segment and numerous number of the precaudal vertebrae as in the present species or not. In either case, the present species is distinguished from *colesi* as shown in the following comparison:

* Personal communication from the original authors.

Characteristic features	*colesi*	*odai*
1. Disc, width in % of total length	48.0; 49.3%	53.5—60.0%
2. Tail, length in % of total length	61.6; 68.6%	53.6—58.4%
3. Precaudal, length in % of total length	50.0; 51.0%	42.3—49.6%
4. Procaudal, length in % of total length	5.86; 6.19%	6.7—10.40%
5. Enlarged thorns on nucha	present	absent

Rhinoraja kujiensis (TANAKA)
(Abbreviated as K; Japanese name, Kuji-kasube)
Fig. 71

Raja kujiensis TANAKA, 1916, p. 173—174 (original description in Japanese). ——, 1916, p. 438. —— JORDAN and HUBBS, 1925, p. 93. —— MATSUBARA, 1935, p. 44 (key). —— 1936, p. 24. —— OKADA and MATSUBARA, 1938, p. 24 (key). —— FOWLER, 1941, p. 381. —— KURONUMA, 1943, p. 102, Kurile Is'l (in Japanese).

Raja tobae (not *tobae*, 1916) TANAKA, 1927, p. 673, figs. 434 and 435.

Raja karagea TANAKA, 1927, p. 784 (n. name for *tobae* TANAKA, 1927). —— MATSUBARA, 1935, p. 44 (key). —— MATSUBARA, 1936, p. 23, fig. 14. —— OKADA and MATSUBARA, 1938, p. 23 (key).

Rhinoraja kujiensis ISHIYAMA, 1952, p. 24, fig. 1. —— ISHIYAMA, 1956 ('55), pp. 271—277, fig. 4 (electric organ). —— MATSUBARA, 1956, p. 139 (key).

Materials examined: 39 specimens (1043—218 mm in total length); 6 egg-capsules; deep sea from off Chôshi to Kushiro (600—800 meters in depth); Oct., 1948 and May to June, 1951.

External: Disc-length 2.0—2.3 (2.21 in average), disc-width 1.5—1.9 (1.73) and tail 1.6—1.9 (1.75) in total length; head 1.9—2.0 (1.97), snout 4.0—4.9 (4.53) and tail 0.6—0.9 (0.86) in disc-length; precaudal length 0.9—1.2 (1.05) in disc-width; diameter of eye 2.3—4.5 (3.45) and interorbital space 2.5—3.6 (3.16) in snout; longer axis of lst dorsal fin 4.3—5.3 (5.07) and that of 2nd dorsal 4.1—5.2 (5.03) in head.

Body with clumsy appearance by having numerous prickles on entire dorsal surface. Disc much shorter than width, which is measured in short excess of tail in the adult, but less than the latter in the young as explained in Fig. 31 K and Table 7 K. Snout very short, flexible and slightly pointed at the tip, as long as 2.1 to 2.3 times in head. Eye moderately large, the horizontal diameter much less than interorbital space when matured, being reversal in the young. Ventral fin with notch in usual degree; two dorsals and caudal fin rather small and prickled; lateral folds in two sides of tail distinct, covering only posterior half of the tail where the electric organ lying internally.

Features of spination is characteristic, being developed with numerous prickles and enlarged thorns on dorsal surface, as has been best figured by TANAKA (1927, fig. 435), i.e. entire dorsal surface studded with numerous prickles with stellate bases, and a row of enlarged thorns developed, running continuously from nucha to dorsal fins, and a pair of the same also occurred on each shoulder. Those prickles covering basal portion of pectoral fin become sparse to some extent when matured, and these phenomena are predominant in the male. Ventral side of the body smooth without scale.

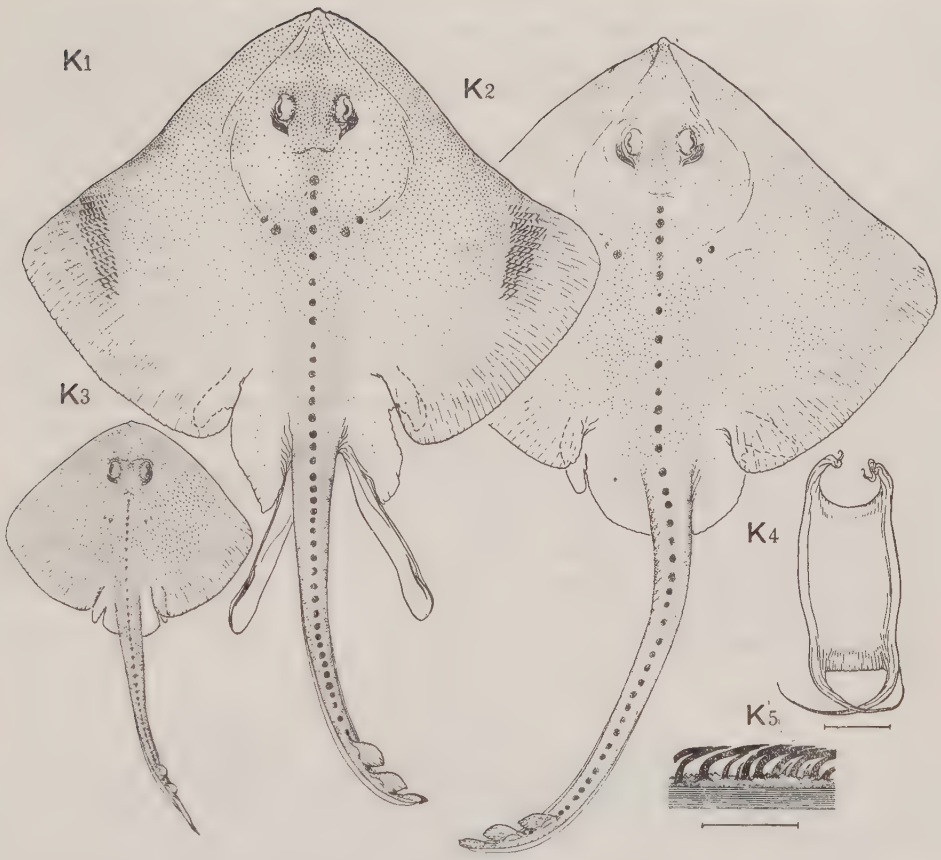

Fig. 71. *Rhinoraja kujiensis* (TANAKA); K_1, adult male (910 mm); K_2, adult female (980 mm); K_3, young female (233 mm); K_4, egg-capsule, scale, 5 cm; K_5, section of capsule-wall, scale 1 mm; from off Same, Aomori Prefecture.

Color of dorsal surface golden drab when fresh, but it changes to brownish gray in the preservation. Ventral boader white as a whole, but several dusky blotches locating branchial region or tail.

Internal: Rostral cartilage rather stout, much shorter than cranium, bearing rostral segment. Rostral appendices distinct, extending posteriorly halfway point of the rostral cartilage (Fig. 26 K).

Precaudal vertebrae numerous, varying from 76 to 83 (79.3 in average), but that of abdominal ones is not so numerous, being from 33 to 38 (K in Figs. 43, 44 and Table 9). Turns of intestinal valves 9—10, and heart valves 4—5 in a row.

Feature of clasper is much worthy for notice in both external and internal structure, viz., pseudosiphon broadly developed on dorsal boader of the glans, of which inside structure is much simple, dorsal terminal 1 is broad, resembling that of the guitarfish, and both ventral and accessory terminals are also characteristic, being in category Types Vt^1 and At^1, respectively. On the basis of features found in the clasper, the present species seems to show the most primitive phase within the organs of Japanes rajids so far as examined in this study (K in Figs. 2, 4, 7~12 and 21).

In this connection, the present writer should like to emphasize that a form which might have firstly differentiated from the genus *Breviraja* may have had the organ similar to that found in the present species, though there found some characters which are thought to show more or less well differentiation than those in the allied ones in the present genus. In fact, the feature of egg-capsule of the present species shows highly specialization as compared with those of the relatives, (Fig. 71 $K_{4,5}$), but the electric organ is not so well-developed (Fig. 35 K).

Notes: This species somewhat resembles Indian rajids, such as *Raja mamillidens* ALCOCH and *R. reversa* LYLOID, in having long tail and many prickles on dorsal surface. But it is suggested that the present species and the other two Japanese forms referred to the genus *Rhinoraja* seem to belonging to different stock from that of the Indians though we are still lacking internal features of the latters.

This species inhabits the deep sea along the Pacific off northern Japan (Fig. 1), where the present species is confound with other northern forms in the landing.

Rhinoraja longicauda ISHIYAMA
(Abbreviated as **L**; Japanese name, Onaga-kasube)
Fig. 72

Rhinoraja longicauda ISHIYAMA 1952 p. 25, fig. 7, Pl. 4. (original description). ——, 1956 ('55), p. 271 (electric organ), fig. 4. —— MATSUBARA 1955, (key), p. 139.

Materials examined: 26 specimens (305–688 mm in total length) including holotype,

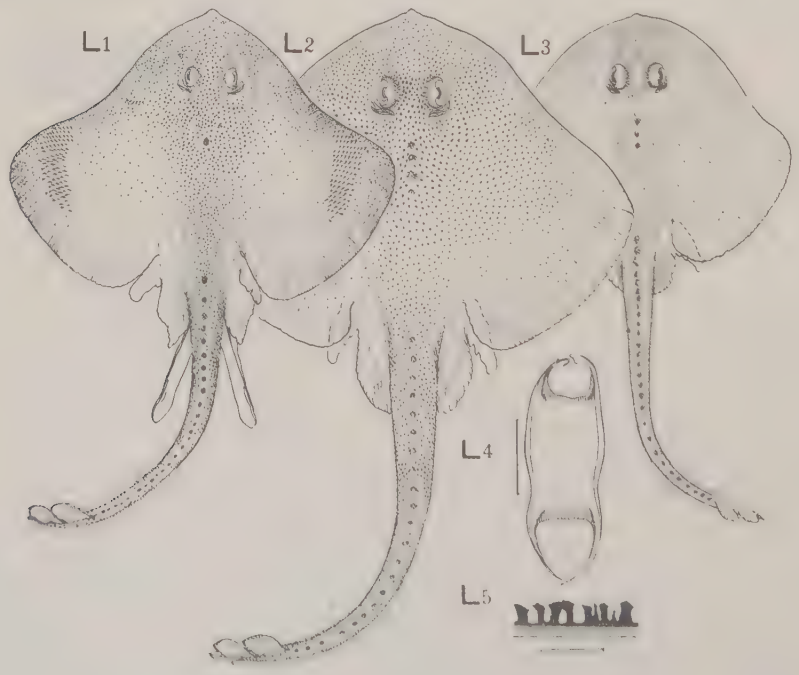

Fig. 72. *Rhinoraja longicauda* ISHIYAMA; L_1, holotype, adult male (665 mm); L_2, adult female (620 mm); L_3, subadult female (305 mm); L_4, egg-capsule, scale 5 cm; L_5, section of capsule-wall, scale 1 mm; from off Hachinohe, Aomori Prefecture.

taken from off Chôshi to Kushiro; Oct., 1948 to June, 1951.

The detail of the present species can be understood in the foregoing paper giving by ISHIYAMA, 1952. The following are given in order to supplement imperfectly known internal features which are credible for the finding not only the systematic significance but also the linealogical verification.

Internal: The clasper structure is of Type 2 (**L** in Figs. 3, 4 and 12), marked from other allied forms by having distinct pseudosiphon accompanied by somewhat reduced dorsal terminal 1 and well-specialized ventral and accessory terminals. Heart valves usually 4 in a row; electric organ very small, the cup-form elements very small in its number (**L** in Fig. 35). Abdominal and precaudal vertebrae, 30—32 and 74—80 (**L** in Figs. 43, 44 and Table 9). Egg-capsule belonging to Type Eg^2 (Fig. 73 $L_{4,5}$).

Notes: It may be conceivable that the present species seems to stand near the species **K** because of finding close relation in their external as well as internal characters, such as long tail with small electric organ, numerous counts of precaudal vertebrae, peculiar feature in rostral cartilage and clasper structure. Further it may be said that the present species may be intermediate between species **J** and **K** in respect to the features as aforementioned. It may be sure from these facts that these three species might have sprung off from an ancestor not very unlike these three species.

Raja LINNAEUS 1758, emend

Raja LINNAEUS syst. Nat., I, 1758, p, 231. Genotype *Raja clavata* LINNAEUS, 1758, European species.

As regards the generic synonyms as well as the generic characters and others of this genus compact description has been given by BIGELOW and SCHROEDER (1953, pp. 138—147) that only brief notes that should call attentions for the designation of the generic significance are given below.

Scales usually sharply pointed without broad stellate bases, much fewer in embryo emarged from the egg-case than in the adult, excepting one species W, possessing three spines on orbital rim, one on the nuchal and one row on dorsal mid-line of tail (Fig. 53), but they become more setose with growth of the fish, resulting remarkable sexual difference in spination of the tail, in most cases (Type Scs). Teeth densely crowded in quincunx order, with round tips in female and young instead of being cuspidate in matured male, and set in such numerous series as 35 to 50 in average (Table 14). Electric organ composed of the disc-form elements even in the young. Clasper relatively large, developed posteriorly with pointed distal tip (Spatula-type) when matured (Fig. 2 **M**). Glans clasper is of Types 8—13, much more complex than that of other genera. Egg-capsule is of Types 5—8, rectangular in general form with either smooth or rather rough surface, with or without short tubular horn at each four corner, and the wall consists of three layers in most cases.

Remarks: The rajids in the Pacific in the northern hemisphere seem to be divided into two groups on the basis of, (1) the structure of snout, (2) the relative length of snout and tail, (3) the mode of development of the prickles and thorns, especially of the tail, (4) the structure of the clasper, (5) the structure and degree of development of the electric organ, (6) the number of abdominal and precaudal vertebrae, and (7) the features of egg-capsule. Two major groups of Japanese rajids are sharply

opposed with each other in these characteristics, although such relation is uncertain in two rajid groups of the northern hemisphere other than those inhabiting in the waters around Japan caused by the absence of the adequate study on whole fauna in the hemisphere. In the present work, however, the writer has dared to subdivide the Japanese rajids of the genus *Raja* into two subgenera on the basis of aforementioned categories,

Key to subgenera of the genus *Raja*

1a. Snout relatively short or moderate in length, the ratio into head-length nearly equal to or slightly less or greater than two times; tail relatively long, the ratio into disc-width in adult about 1.2—1.5; nuchal spine more than one in most cases, and tail spines three rows in both sexes except for male of species M, or more numerous in female; electric organ less or moderately developed; glans clasper is of Types 8–10; abdominal vertebrae relatively few, less than 30; intestinal spiral valves 5 to 8; body moderately large or small in parallel with size of egg-capsule ..... *Okamejei*, n. subg.

1b. Snout relatively long and stout, the ratio into head-length never exceeds two times; tail relatively short, the ratio into disc-width about 1.5—1.8; nuchal spine mostly 1, and tail spines set in one row in male and three to five in female when matured; electric organ moderate or markedly developed; glans clasper is of Types 11—13; abdominal vertebrae rather numerous, varying from 30 to 34; intestinal valves 9 to 15; body and egg-capsule usually large ..... *Tengujei*, n. subg.

*Okamejei**), n. subg.

The establishment of the present subgenus is contrasted to the forthcoming one, basing the following characteristics which are thought to be different genetically from those in the relative as mentioned in the foregoing key.

The features diagnostic to the present subgenus are the relatively shorter snout, numerous rows of spines developed on the tail of male except species M, less developed electric organ, much more specialized structure revealed in the clasper, and relatively fewer number of the abdominal vertebrae. These characteristics are revealed in such seven species as **M**, **N**, **O**, **P**, **Q**, (**Q′**), **R** and **S**, all of which are the dwellers in either the shallower or more southerly waters than the species referred to the forthcoming subgenus.

Type species: *Raja fusca* GARMAN, 1885

Key to species and subspecies of the subgenus *Okamejei*

1a. Tail armed with one row of enlarged spines along mesial line in matured males instead of being three rows in the adult females though they have merely one row in young ones; venter uniform gray instead of being very variable with numerous brown patterns and having a distinct ocellus on each base of the pectoral fin; membranous folds along both sides of tail ill-defined especially in the adult. Clasper is of Type 8 ..... *kenojei* (Fig. 73; Pl. II, M)

1b. Tail armed with three or more numerous rows of enlarged spines in adult of both sexes though the young commonly having only one row of the spines; venter mostly white except marginal portion; dorsum mottled with various patterns with or without pectoral ocellus; membranous folds of tail distinct even in the adult. Clasper is of types 9 or 10.

* Modeled after *Okame* in Japanese tradition, meaning a female with low-nose, and *jei* is a skate and ray in Japanese, i.e. low-nosed skate.

2a. Snout rather long, pointed at distal tip, longer than 2.5 times the width of interorbital space; rostral cartilage in adult relatively long, as long as or longer than cranium. Clasper is of Type 9.

3a. Procaudal portion relatively long, subequal to or greater than one-third the length of tail; pectoral ocellus absent in the young. Electric organ small, not reaching to the base of the tail. Clasper is of Type 10, characterized by having much specialized sentinel.

4a. Eye smaller than interorbital width; in the adult, 1—3 nuchal spines running in a row; tail armed with three rows of spines in male instead of being numeous rows in female; dorsum of disc and pelvic fins dressed in various color patterns with many brown spots; abdominal vertebrae ranging from 28 to 29 (28.4 in average). Clasper characterized by having a distinct sentinel and rhipidion monolobed ..... *hollandi* (Fig. 75)

4b. Eye longer than interorbital width; in the adult, 2—3 nuchal spines setting in triangular pattern in most cases; tail spines very sharp, and sparse, arranging in three rows in male instead of being five in female; dorsum of disc and pelvic fins mottled with numerous brown patterns, but without brown spots; abdominal vertebrae 25 to 26 (25.4 in average). Clasper specialized in having remarkably long spike and rhipidion bilobed ..... *macrophthalma*, n. sp. (Fig. 76)

3b. Procaudal portion of tail relatively short, reduced to below one-third the length of tail; pectoral ocellus usually present in the young. Electric organ moderatly developed, reaching anteriorly to the basal portion of tail. Clasper is of Type 9, marked with bulgy developed sentinel.

5a. Nuchal spines varying from 1 to 3, but mostly 1 even in the adult; tail spines growing in three rows in adult male, but numerous rows setting irregularly in female; ventral surface colorless without black blotch. Clasper characterized by having monolobed rhipidion and broad dorsal terminal 1 ..... *acutispina*, n. sp. (Fig. 74; Pl. II, N)

5b. Nuchal spines numerous, covering 2—16 in adult; tail spines growing three rows in adult male, but five regular rows in female; ventral surface dressed with dusky blotches in many cases. Clasper characterized by having bilobed rhipidion and much narrow dorsal terminal 1.

6a. Snout relatively short; tail longer than that of 6b as explained later on. Accessory terminal 1 of clasper elongated posteriorly and as long as the accessory terminal 2 (Q in Figs. 5 and 18) ..... *porosa meerdervoorti* (Figs. 77, 78 and Pl. II, Q)

6b. Snout relatively long; tail shorter than that of 6a. Accessory terminal 1 elongated posteriorly, reaching beyond tip of accessory terminal 2 (Q′ in Figs. 5 and 18) ..... *porosa tobae* (Figs. 77 and 79)

2b. Snout very short, pointed at the tip, less than 2.5 times the width of interorbital space; rostral cartilage shorter than cranium in the adult. Clasper is of Type 9.

7a. Ground color of dorsum of disc deep brown, furnished with numerous blackish spots and distinct pectoral ocellus; nuchal spines 3—5 in the adult; tail spines developed in three distinct rows in both sexes; precaudal vertebrae 39—43 (41.0 in average). Clasper marked with the rhipidion bilobed ..... *fusca* (Fig. 80)

7b. Ground color of dorsum of disc brownish yellow, scattering numerous brown spots and having distinct pectoral ocellus; in the adult, nuchal spines 1—3,

but mostly 1; tail spines set in three rows in male, instead of being numerous irregular rows in female; precaudal vertebrae 42—45 (43.4 in average). Clasper defined with the rhipidion monolobed .... *schmidti*, n. sp. (Fig. 81; Pl. III, S)

Raja (*Okamejei*) *kenojei* MÜLLER et HENLE
(Abbreviated as M; Japanese name, Gangi-ei)
Figs. 57, 73; Pl. II, M

Raja kenojei (BÜRGER) MÜLLER et HENLE, 1841, p. 149, pl. 47, Nagasaki, southern Japan (original description). —— RICHARDSON, 1846, p. 197, Seas of China and Japan. —— SCHLEGEL, 1850, p. 308, Nagasaki. —— BLEEKER, 1853, p. 22, Nagasaki; China. —— DUMÉRIL, 1865, p. 556 (compiled). —— GÜNTHER, 1870, p. 461, Japan. —— NYSTRÖM, 1887, p. 51, Nagasaki. —— JORDAN and SNYDER, 1901, p. 41 (reference). —— SCHMIDT, 1904, p. 289 (noted). —— JORDAN and STARKS, 1906, p. 515, Port Arther (listed). —— JORDAN and METZ, 1913, p. 5, Port Arther. —— JORDAN and THOMPSON, 1914, p. 208, Misaki (listed) —— JORDAN and HUBBS, 1925, p. 113 (pars), Japan, from Tokyo to Nagasaki. —— UI, 1929, p. 21, Wakayama. —— FOWLER, 1930, p. 501, Japan. —— SOLDATOV and LINDBERG, 1930, p. 19, Far East Sea (reference). —— TANAKA, 1931, p. 15, Japan (listed). —— SCHMIDT, 1931, p. 11, Japan; Korea. —— WANG, 1933, p. 105, fig. 7, Chusan. —— MORI and UCHIDA, 1934, p. 3, Korea (listed). —— MATSUBARA, 1935, p. 45 (key). —— TARANETZ, 1935, p. 89 (reference). —— MATSUBARA, 1935, p. 45 (key in Japanese). —— OKADA, UCHIDA and MATSUBARA, 1935, p. 59, pl. 10. —— MATSUBARA, 1936, p. 29 (key in Japanese). —— OKADA and MATSUBARA, 1938, p. 25, Japan (key in Japanese). —— KAMOHARA, 1938, p. 6. Kôchi (listed). —— FOWLER, 1941, p. 374, (reference). —— BOESEMAN, 1947, p. 224 (pars). —— CHEN, 1948, p. 5. —— HIKITA, 1950, p. 112, Japan Sea (listed). —— ISHIYAMA, 1950, p. 30, figs. 1 and 2. Japan Sea (egg-capsule). —— HERRE, 1953, p. 39 (listed). —— ISHIYAMA, 1955, p. 271, figs. 2—4, Japan (electric organ). —— MATSUBARA, 1955, p. 137, Japan (key). —— HONMA, 1955, p. 50, Sado, Japan Sea (listed). —— KAMOHARA, 1955, p. 4, pl. 4.

Raja meerdervoortii BLEEKER, 1860, p. 66, Nagasaki. —— PIETSCHMANN, 1908, p. 642, Japan. —— IIZUKA and MATSUURA, 1920, p. 187, Asamushi.

Raja japonica NYSTRÖM, 1887, p. 52, Nagasaki.

Materials examined: 102 specimens (97-662 mm in total length), 2 embryos and 10 egg-capsules; shallow waters from off Aomori Prefecture to moderate depth off southern Japan; 1947—1954.

External: Snout moderate in length, the ratio into head of adult greater in male than in female (M in Table 6). Tail stiffened, rod-like in shape, longer in male than in female when matured (M in Table 7). Membranous fold of tail scarcely visible in the adult, but apparent in the young. Dorsum of body smooth excepting tip of snout, orbital rim, nuchal region and tail; the spines on nuchal and tail are characteristic in this species, thus: nuchal region armed usually with only one spine, but occasionally with 2 to 3 ones; tail armed with one row of enlarged spines along mesial line in matured male, but three rows in the female (M in Figs. 36 and 57), as is the case with species T and V. Ventral side entirely smooth with exception of tip of snout.

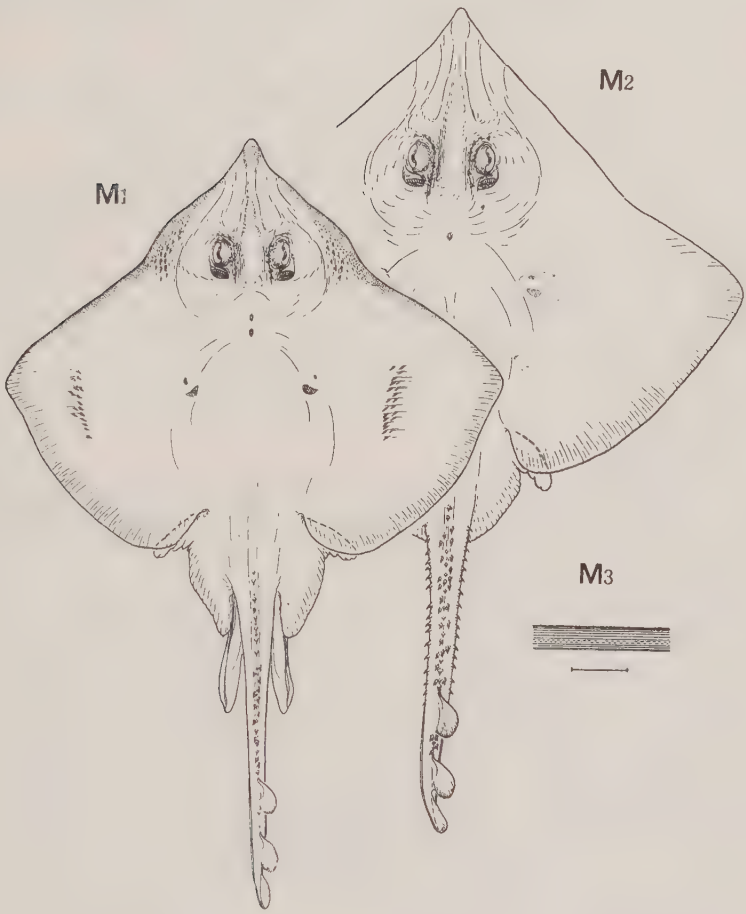

Fig. 73. *Raja kenojei* MÜLLER et Henle; M_1, adult male (820 mm); M_2, adult female (880 mm); section of egg-capsule, scale 1 mm; from the East China Sea.

Color of dorsum brown, mottled with lighter or darker patterns, and always with pectoral ocellus, which is larger than eye, furnished with a white or pale center and marked with 2 dark rings with one inside the other (Pl. II, M). Ventral side uniform gray, giving remarkable specific hue.

Internal: Rostral cartilage rather stout, thickened at the basal portion, and almost as long as cranium; rostral appendices moderately developed; both anterior and posterior fontanella broadly opened with a boat-like foramen, and the posterior one not constricted at the midway portion (Fig. 27 M).

Abdominal and precaudal vertebrae covering respectively 27—28 (28.3 in average) and 44—47 (44.8 in average) (M in Figs. 43, 44 and Table 9). Intestinal valves 7—8 (7.6 in average), and heart valves in a row 4—5, but mostly 4 (Table 11). Electric organ medium in both number of the elements and size (M in Figs. 36, 39 and Table 8). Clasper is of Type 8 (M in Figs. 2, 5 and 17).

Developmental stages: Snout relative to head length reveals in much complex

change with growth of body, contradistinguishing between two sexes as shown in Fig. 25. Tail relative to disc-width also changes in no small extent with growth of the fish (Fig. 32). Thus, it may be difficult to show exactly those constant values in relative lengths of the snout and tail.

Color and pattern of the dorsum as well as that of ventral side are discernible characteristic in the present species inasmsch as the similar hue is found to occur in common without exception throughout the life of the fish.

Spination of the tail increasingly changes with growth of the fish from the young to the adult. In the newly hatched fish, 9 to 12 spines are found to develope in one row in both sexes, interrupted posteriorly by an intervention of 1st dorsal fin, and afterward the spination becomes three rows in female as the fish attains to maturation with total length of about 450 mm, although it is one row in male even in the adult, but the adult male has both the alar and malar spines (**M** in Figs. 36, 57 and 73).

Egg-capsule: Moderate in size, representing Type 6, characterized by having smooth surface with thicker silky hairs and also by having the wall composed of three layers of the tissue (Fig. 73 M_3).

Distribution: The present species is an endemic form, ranging from the northern extremity of the main island of Japan to the East China Sea throughout the coastal waters on both sides of the island, where the range of vertical distribution covers from about 20—30 meters (northern district) to 70—80 meters or deeper (southern district). It may be interest to note that the Tsugaru Strait might be a barrier to the present species because no specimen has been obtained in the waters off Hokkaido.

Notes: There were found much many instances confusing the identification of the present species among the Japanese rajids since the original description has been given by MÜLLER and HENLE (1841) having used badly preserved immature specimen of a male. By detailed examination of the original description compared with many specimens gathered from various localities the present writer has attained to have a compact knowledge of the identification of the present species without any space for doubt, as mentioned above. Further, it may be sure to believe that the present species has more or less close relation to species **T** in such noteworthy characters as the clasper structure, number of precaudal vertebrae, spination of tail in the adult and the construction of egg-capsule.

As regards the age and growth of the present species the present writer has given the details elsewhere in this account (p. 119).

Raja (*Okamejei*) *acutispina*, n. sp.
(Abbreviated as **N**; New Japanese name, Moyô-kasube)
Fig. 74; Pl. II, **N**

Materials described: Holotype, 413 mm, off Shimane Prefecture, Sea of Japan, Dec. 3, 1952; paratypes, 67 specimens (123—435 mm in total length) and 6 egg-capsules, from off Kanaiwa, Ishikawa Prefecture, to the Tsushima Strait; 1952—'55.

External: Disc-length 1.72, width 1.49, tail 2.09 in total length; head 1.79, snout 4.00, precaudal 1.84, procaudal 3.58, in disc-length. Snout 2.23, 1st and 2nd dorsal fins 4.78 and 4.96, respectively, and caudal fin 8.33 in head. Interorbital width 3.62, eye-diameter 3.52 in snout length.

Body has more gentle appearance than species **M**. Anterior edge of disc slightly undulated, elongated anteriorly into a sharp end. Tail rather stout but depressed

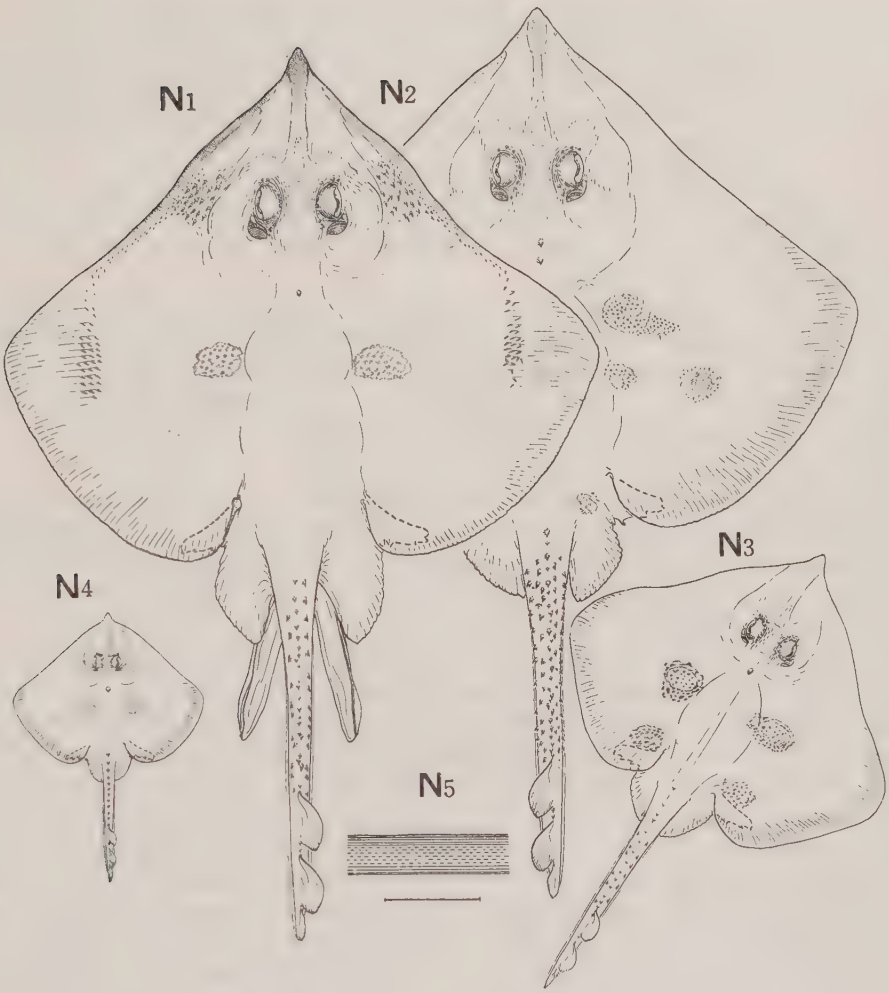

Fig. 74. *Raja acutispina*, n. sp., N_1, holotype, adult male (413 mm); N_2, adult female (405 mm); N_3, subadult female (235 mm); N_4, young male (112 mm); N_5, section of egg-capsule, scale 0.5 mm; $N_{1,2}$, off Shimane Prefecture, the Japan Sea; $N_{3,4}$, off Maizuru, the Japan Sea.

dorso-ventrally (Depressed-type), 1.21 and 1.39 times in disc-length and disc-width, respectively. Interorbital space shallowly concave, the width trifle smaller than diameter of eye. Pelvic fin commonly notched with broad anterior lobe. Clasper is of Spatula-type, stiffened with pointed posterior tip, which extends to the halfway point of tail; dermal fold distinct, growing from base to the extremity of tail. Two dorsal fins moderately large; the lst one begins at the posterior one-third point of tail; caudal fin distinct, just as long as interorbital width.

Dorsal surface of disc wholly smooth except for anterior oblique margins, orbital rim and nuchal center, where the disc more or less armed with spines and prickles, i.e. a band of minute prickles on anterior oblique margin on each side and on rostral axis, five enlarged spines on orbital rim, only one large spine on nucha, and patches

of alar and malar spines on both sides. Three rows of spines run on tail; minute prickles covering dorsal fins, but the caudal fin naked (Fig. 75 N_1).

Color of dorsum of disc mottled with various color patterns, bearing distinct pectoral ocellus on each side (Group 5); venter of body colorless as a whole, excepting marginal portion with faint orange yellow. Entire body surface extremely slimy when fresh (Pl. II, **N**).

Internal: Rostral cartilage rather long, longer than the cranium; rostral appendix distinct, a little shorter than half the length of rostral cartilage; anterior fontanelle triangular in shape with round corners, and the posterior one boat-like in general appearance (Fig. 27 **N**).

Electric organ rather small, scarcely reaching anteriorly the center of posterior ends of pelvic fins (Fig. 36 **N**). Vertebral counts 26–29 + 40–42 (**N** in Figs. 43, 44 and Table 9). Intestinal valves 5–8 (6.8 in average). Heart valves 5 in a row, in most cases (Table 11).

Clasper is of Type 8, remarkable in having bilobed rhipidion, small spike and broad dorsal terminal 1 (**N** in Figs. 5 and 17).

Egg-capsule: Egg-capsule of the present species has close resemblance with that of species **M**, **O** and **S**, in having three layers in the capsule-wall, but the capsule of the present species is distinct from that of the relatives by having much chickened pulpy layer with 60% of total thickness of the wall and having thick cover of the silky fibres over the surface (Fig. 74 N_5).

As shown in the Fig. 74 the snout is more acute in the adult male than in the female. The relative ratios of snout and tail change with growth of the fish as is the case with other species (Fig. 25 and Table 6). Namely, the change of proportional ratio of snout in length of head is more remarkable in the male than in the female, but reverse is the case in the change of ratio of the tail in width of disc.

Nuchal spines vary from 1 to 3, in most case 1; increase of tail spines from one to three rows occur at a total length of about 250 mm (Fig. 75 $N_{3,4}$); spines on orbital rim are developed with variation covering from 5 to 8, but in most cases 6 or 7 (N_3 in Fig. 74); minute prickles are crowded on anterior oblique margins of the disc in adult male, but they are developed only on distal portion of the rostral axis in the adult female. The individual variation of color and pattern on dorsum is great in the present species, and in the accompanying photograph (Pl. II) is shown that of the most common case; the pectoral ocellus is always present on two sides.

The present species inhabits only the coastal waters in the Sea of Japan, ranging from Noto Peninsula, Ishikawa Prefecture, to probably the Tsushima Strait, where the fish is usually caught by the motor trawler or the long-line.

Remarks: From external features the present species is liable to confuse with the species Q(Q′), especially in their young stages and frequently in their color and patterns. But, the two species are distinguishable externally from each other, thus; i) snout of the present species is more acutely pointed than that of the relative, and marginal portion of ventral side of disc of the present species is orange yellow, though it is grayish orange in the relative, in the young, ii) interorbital width of the present species is trifle greater than diameter of eye, but it is apparently greater than the diameter in the other, iii) nuchasl pines are fewer in the present species than in the other as explained later on, in the adult, and iv) tail spines in the adult female are set in numerous irregular rows in the present species, but they are in

five regular rows in the other (c.f. Figs. 74 and 77—79).

On the basis of internal features, the present species shows more close affinity with species M than with other species in the southern members, especially in the male organs. It may be considered that the present species may have been specialized from an ancestor not very unlike the species M, as the present species have been adapted in the shallower water than the species M inhabits.

Raja (Okamejei) hollandi JORDAN et RICHARDSON
(Abbreviated as O; Japanese name, Isago-gangi-ei)
Fig. 75

Fig. 75. *Raja hollandi* JORDAN et RICHARDSON; O_1, adult male (480 mm, 3—4 ages); O_2, adult female (500 mm, 3—4 ages); O_3, subadult male (320 mm, 2 ages); O_4, young male (160 mm, 1 age); O_5, section of egg-capsule, scale 1 mm; from the East China Sea.

Raja hollandi JORDAN et RICHARDSON, 1909, p. 163, Pl. 64 (original description), Takao, Formosa. —— FOWLER, 1929, p. 501 (reference). —— MATSUBARA, 1935, p. 44 (key). —— MATSUBARA, 1936, p. 25, fig. 16. —— KAMOHARA, 1938, p. 6, Kôchi. —— OKADA and MATSUBARA, 1938, p. 24 (key). —— ISHIYAMA, 1950, p. 30, figs. 1, 2, off Shimane Prefecture (egg-capsule). —— ISHIYAMA, 1951, p. 636, figs. 1—4, East China Sea (age-determination). —— ISHIYAMA, 1955, p. 271, fig. 4 (electric organ). —— ISHIYAMA, 1956, p. 99, fig. 2 (age-determination). —— MATSUBARA, 1955, p. 137 (key).

Raia hollandi, GARMAN, 1913, p. 351 (compiled).

Raja porosa (non GÜNTHER) TORTONESE, 1936, p. 36, fig. 4, Hong Kong. —— CHEN, 1948, p. 5, Formosa.

Materials examined: 59 specimens (190—540 mm in total length), off Kôchi (the Pacific shelf) and Shimane (the Japan Sea shelf) to the South China Sea; 1950—1954.

External: Snout rather long, pointed at the tip, the length relative to head-length in the adult shorter in male than in female, the ratio being 1.95—2.15 and 1.80–1.95 times, respectively (○ in Fig. 25 and Table 6). Tail slender, roundish in cross section of the main portion, the relative length also different between two sexes in the adult as in case of the snout, the ratio in width of disc 1.25 and 1.44 times in average of male and female, respectively (○ in Fig. 32 and Table 7). Interorbital space shallowly concave, the width greater than or nearly as long as diameter of eye. Procaudal portion rather long, retaining rather long caudal fin, which is about twice as long as interorbital width. Both dorsum and ventral side of the body naked with exception of tip of snout, orbital rim, nuchal and tail portions as is the case with other southern forms. Nuchal spines 1 to 2, but mostly 1; tail armed with three rows of spines in matured male, but five irregular ones in the female (Fig. 75).

Dorsum brown, densely covered with small black spots with the size of coffee grains, which show various patterns on pectoral fins. Underside of disc pale gray or whitish except for marginal portion.

Internal: Rostral cartilage nearly as long as cranium, which is twice as long as rostral appendices (Fig. 27 ○).

Abdominal vertebrae 28—29 (28.4 in average); precaudal vertebrae 38—42 (40.8 in average) (○ in Figs. 43, 44 and Table 9). Intestinal valves 6—7 (6.8 in average) (Table 10); heart valves mostly 4 in a row (Table 11). Electic organ small, extending from tip of tail to the portion behind the base of the same (Fig. 36 ○). Structure of clasper discriminated from the relatives, being referred to Type 10 of the organ (○ in Figs. 5 and 17).

Developmental stages: Proportion of snout-length into head-length rather constant in female larger than 100 mm in disc-width, but the ratio markedly changes in male larger than 250 mm in disc-width. By the change of relative length of the tail with growth of the fish the two sexes are also distinguished (○ in Fig. 32 and Table 7). Development of accessory spines on tail becomes evident when the fish attains about 300 mm in total length (Fig. 76 O_3).

Color and pattern of dorsum appear to be invariable throughout from the young to the adult, and the pattern formed by numerous black spots is attractive character in fresh condition, but the pectoral ocellus is always absent in the youg.

Egg-capsule: The egg-capsule of the present species is quite similar to that of

species **M** or **N** at first sight, but they are distinguishable histologically from each other on basis of degree of development of the pulpy layer (c. f. p. 47), although they are all referred to Type 6 in the character of this organ.

Distribution: This species is known to cover southern regions from offing Kôchi in the Pacific and Shimane in the Japan Sea to the South China Sea, where rather large amounts of the fish are caught by the motor-trawler.

Notes: JORDAN and RICHARDSON's original description of this species was based on an immature male, so that the proportions of some dimensional parts of the body differ in some extent from those of the adult. This species can be distinguished externally from others, at least in having blackish brown spots on the dorsum and relatively long caudal fin even in the adult. The present species is closely related to the species **P** in some fundamental characters, such as the structure of clasper, number of vertebrae and features of egg-capsule. Probably, the two species may be offshoots sprung from a common ancestor.

Previously, the present writer has examined rather large amount of specimens of this species caught from the East China Sea in order to determine the age-composition of the fish (ISHIYAMA, 1951). As a result, it becomes evident that the age of the fish can be determined by the examination of vertebral centrum as aforementioned, and the fishes representing various ages are now shown in this account.

Raja (*Okamejei*) *macrophthalma*, n. sp.
(Abbreviated as **P**); Japanese name, Medama-kasube)
Fig. 76

Raja macrophthalma ISHIYAMA, 1950, p. 30, fig. 1, 2, off Hamada, Shimane Prefecture (egg-capsule). —— ISHIYAMA, 1955, p. 271, figs. 1—4, off Shimane Prefecture (electric organ).

Materials described: Holotype, 347 mm, Miya fish market, Aichi Prefecture, March 13, 1950; paratypes, 71 specimens (94—369 mm in total length) and 2 egg-capsules, off Shimane Prefecture and Shimonoseki fish market (the Japan Sea), and off Aichi and Shizuoka Prefectures, Kumano-nada, and Yawatahama, Ehime Prefecture (the Pacific); 1950—1954.

External: Disc-width 1.57, disc-length 1.92, tail 1.89, head 3.58 in total length; head 2.26, snout 5.00, precaudal length 1.92, procaudal length 3.21 in disc-width; interorbital width 4.19, eye-diameter 3.52, longer axis of both dorsal and caudal fins 2.09, and ventral incision 2.0 in snout.

Snout rather long and pointed; anterior oblique margins of disc strongly undulated. Interorbital space concave, smaller than eye, which is relatively large*). Tail stiff, slender and rather depressed; precaudal elongated, 2.67 times in length of tail. Dorsals separated by a distance equal to base length of the fin. Lateral fold of tail inconspicuous, extending anteriorly beyond distal tip of the pelvic fin. Clasper stout and elongated, extending as far beyond midway point of tail posteriorly.

Spination of dorsum rather similar to that of the preceding species **O**, i. e., tip of snout, anterior oblique margin of disc, orbital rim, nuchal and tail portions are all setose in some extent, of which the spination on last three regions is characteristic of the present species. Namely, 5 spines on orbital rim, 2 spines on nucha and three rows on tail; two dorsal and caudal fins and both sides of tail rearward of the 1st dorsal are also prickly. Ventral side of body smooth, without any scale (Fig. 76 P_1).

* The specific name was derived from this characteristic.

Dorsum brown, furnished with numerous dark brown spots, which crowd to make roundish patterns scattered at places on main portion of disc. Ventral white with numerous sensory pores of dark gray.

Internal: Rostral cartilage slender, much longer than cranium, with exceedingly projecting median process; rostral appendix rather long, more than half the length of cranium. Both anterior and posterior fontanella broadly opened, but their anterior and posterior extremities pointed (P in Fig. 27). Electric organ less developed, scarcely reaching anteriorly to posterior extremity of the pelvic fin (P in Fig. 36). Abdominal vertebrae 25—26 (25.4 in average); precaudal vertebrae, 38—43 (40.4 in average)(P in Figs. 43,44 and Table 9). Intestinal valves 5—7; heart valves mostly 4 in a row. Clasper is of Type 10, marked with specialized sentinel and accessory terminal 2 (P in Figs. 5 and 17).

The above external characters are derived from the holotype of full-matured male measuring 347 mm in total length, but the internal characters as well as following external ones are given by paratypes.

Ratio of snout-length into head-length 1.9—2.1, but it is trifle greater in male than in female in adult (Fig. 25 and Table 6). Ratio of tail-length into disc-width is also not so different between two sexes in stages older than adolescent, but the trend reversals as compared with the case of snout (P in Table 7).

The newly born young (Fig. 76 P_3) is equipped with a common tract of spines, viz., 3 supraorbital, 1 nuchal and one row of tail ones, which are increased by addition of accessory ones as the fish attains about 200 mm in total length. The difference in the spination is rather distinct between the sexes when matured, viz., in the female, anterior oblique margin of disc quite smooth with exception of the tip of snout (Fig. 76 P_2), while in the male the portion densely armed with numerous prickles and malar spines (Fig. 76 P_1); number of spines on orbital rim mostly 6 in female but 5 in male; nuchal spine ranges 2—3, setting usually in triangular pattern in female instead of being 1—2 in a row in male; 5 rows of spines on tail in female, while 3 in male without exception.

In color pattern on dorsum, there is no difference between young and adult in most cases, but sometimes it happens to occur some dusky blotches on the dorsal as well as on ventral side in the adult.

Egg-capsule: The egg-capsule is of Type 6, the smallest one so fas as known to us measures 39 to 42 mm in length exclusive of the horns (Fig. 76 P_1).

The present species is found to occur in the coastal waters ranging from the middle regions offing of Shizuoka and Shimane Prefectures to the south of our main island, but probably is found around Kyusu.

The present species is often captured together with such three related forms as **N**, **Q′** and **S**, which are found to inhabit the southern waters, but they are distinguishable externally from each other in relative length of both snout and procaudal portion, relative size of eye-diameter, mode of arrangement of spines, especially on nuchal and tail portions, and presence or absence of pectoral ocellus in addition to the size of body when matured.

Remarks: This species closely related to species O in their fundamental characters, such as structure of clasper, configuration of rostral cartilage and cranium, vertebral counts, and degree of development of electric organ. In this connection, the two species may be congeneric descendants, which might have been sprung into different but neighbouring waters.

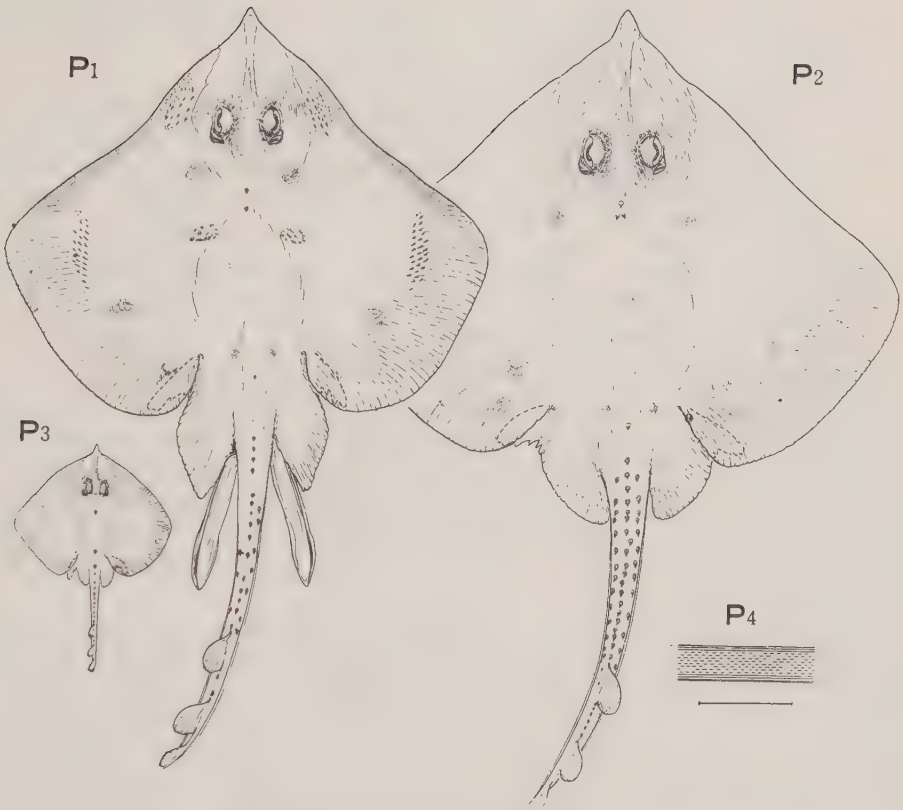

Fig. 76. *Raja macrophthalma*, n. sp.; P_1, holotype, adult male (347 mm); P_2, adult female (369 mm); P_3, young female (120 mm); P_4, cross section of egg-capsule, scale 0.5 mm; $P_{1,3}$ from off Aichi Prefecture; $P_{2,4}$ from off Shimane Prefecture, the Sea of Japan.

Raja (*Okamejei*) *porosa meerdervoorti* GÜNTHER
(Abbreviated as Q; Japanese name, Komon-kasube)
Figs. 77 and 78; Pl. II, Q

?*Raja chinensis* BASILEWSKY, 1855, p. 215, Pepin, China. —— GARMAN, 1913, p. 356 (compiled).

Raja porosa GÜNTHER, 1874, p. 154, Chefoo, China (original description). —— ?MORI, 1928, p. 3, Mokpo, Korea (listed). —— FOWLER, 1929, p. 501 (reference). —— FANG and WANG, 1932, p. 264, Chefoo, China. —— ?MORI and UCHIDA, 1934, p. 26, Mokpo, Korea (listed). —— LIU, 1932, p. 161, Tsingtao, China. —— OKADA and MATSUBARA, 1938, p. 25 (key). ——? KAMOHARA, 1952, p. 11, Kôchi. —— (pars) MATSUBARA, 1955, p. 137 (key).

Raia porosa GARMAN, 1913, p. 154, China.

Raja meerdervoorti (*pars; non* BLEEKER) JORDAN and FOWLER, 19303, p. 605, fig. 7, Tokyo; Nagasaki; Kôbe; Wakanoura; Hakodate. —— ?JORDAN and METZ, 1913, Fusan, Korea (listed).

Raja meerdervoortii (*pars; non* BLEEKER) JORDAN, TANAKA and SNYDER, 1913,

p. 26, fig. 13, Japan (listed). —— ?MORI, 1928, p. 3, Fusan, Korea (listed). —— HONMA, 1955, p. 212, Sado Is'l, Niigata Prefecture (listed).

Raja meerdervoortii meerdervoortii ISHIYAMA, 1950, p. 30, figs. 1, 2 (in Japanese), off Akita, Sea of Japan (egg-capsule).

Raja katsukii TANAKA, 1927, p. 662, figs. 426—428, Niigata and Aomori, Sea of Japan. —— MATSUBARA, 1935, p. 45, (key). —— MATSUBARA, 1936, p. 26, fig. 17 (reference). —— OKADA and MATSUBARA, 1938, p. 24 (key). —— FOWLER, 1930, p. 501 (compiled). —— FOWLER, 1941, p. 371 (compiled).

Materials examined: 13 specimens, 243—365 mm. in total length and 2 egg-capsules; coastal waters of the Sea of Japan, offing of Kasumi, Tsuiyama, Niigata, and Funakawa; 1948—1954.

External: Snout very short, pointed at distal tip, the length into head length 2.07 times on average with range from 1.97 to 2.31, discriminating between sexes (Fig. 25 ♀): tail short, depressed dorso-ventrally becomes somewhat slenderer posteriorly, the length into disc-width 1.38 times in average with range from 1.28 to 1.53, varying between sexes (Fig. 32 ♀); interorbital space shallowly concave, the width apparently broader than eye-diameter, being 3.47 to 4.08 times as broad as eye diameter with 3.39 times in average; the width into snout-length varies 2.74 to 3.39 times with 3.05 times on average.

Anterior marginal portion of disc including mesial plane on rostral cartilage studded with prickles, which are denser in male than in female; posterior and mesial portions of disc furnished with prickles in female, but smooth in male; a row of 2 to 5 spines on nuchal; orbital spines present; spines on tail setting in 3 regular rows in male, but in 5 similar rows in female; two dorsal and caudal fins usually smooth except for original portions of dorsals; ventral surface entirely smooth except for tip of snout which is armed with a few scales (Fig. 77 ♀1,2).

Variation of color pattern on dorsal side of disc remarkable, being mottled with various hue, but the pectoral ocellus usually distinct; ventral side of disc generally white, bearing blotted dapples on central portion in some cases.

Internal: Rostral cartilage short, about as long as cranium-length; rostral appendices small, but distinct as in other members of this subgenus; anterior and posterior fontanella long, the posterior one not constricted at the middle portion (Fig. 27 ♀).

Abdominal and precaudal vertebrae 27.3 and 41.1 in average, respectively (♀, ♀′ in Figs. 43, 44 and Table 9). Intestinal valves 7.6 in average (♀, ♀′ in Fig. 48 and Table 10). Heart valves larger in number than in any Japanese rajids, ranging 4 to 6 in a row (♀, ♀′ in Table 11). Electric organ rather small and the elements of the organ rather few, occupying both sides of whole tail (Fig. 36 ♀).

Clasper is of Type 9, characterized by having large sentinel and rhipidion in external, and in having symmetrically elongated accessory terminal 1 and shorter accessory terminal 2, as has mentioned elsewhere (♀ in Figs. 5 and 18).

Developmental stages: Snout shorter and more pointed in the young than in the adult, the length into head-length varies with growth of the body (♀ in Table 6). Tail relatively long, depressed even in the young, the length into disc-width change with growth of the fish as in case of other members of this genus (♀ in Table 7). Increase of spines on tail from one to three or five rows starts at a total length of about 200 mm (Fig. 78 ♀). The variation of color and patterns in the developmental stages also remarkable, giving various hue of the skin—olive to dark sepia with or without pale

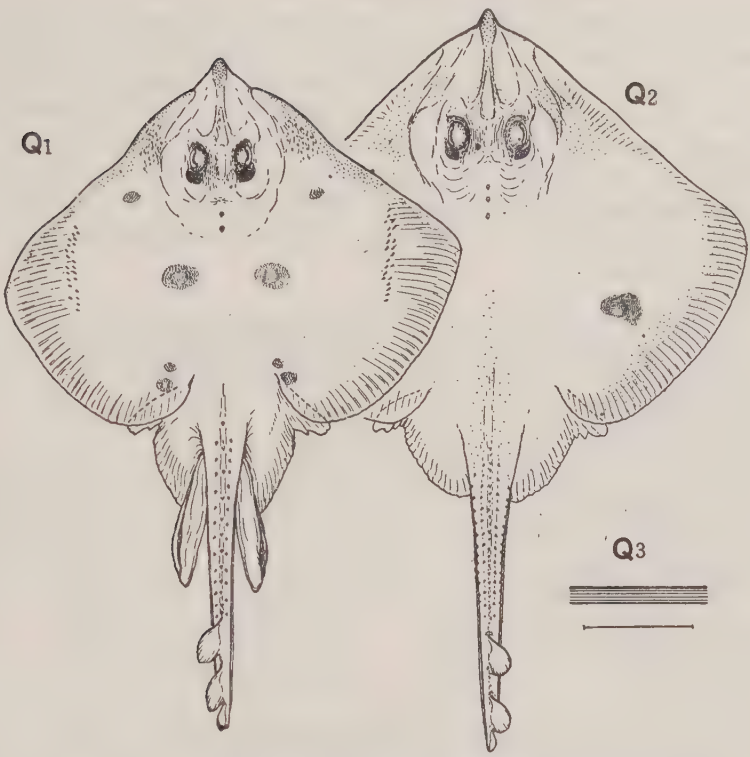

Fig. 77. *Raja porosa meerdervoorti* GÜNTHER; Q_1, adult male (335 mm); Q_2, adult female (393 mm); Q_3, section of egg-capsule, scale 1 mm; from off Kasumi, Hyogo Prefecture, the Sea of Japan.

spots, which are sometimes few and many, and sometimes numerous and small as is the case with the adult, but pectoral ocellus always present even in very young fish, and marked with dark brown ring on both sides of disc.

Egg-capsule: The capsule belonging Type 5, distinguishable from others in its small size (43 to 59 mm long exclusive horns) and in having very thin capsule-wall (0.15 mm thick), which is composed of two layers without pulpy layer (Figs. 22 Q, and 77 Q_3).

Notes: The present subspecies is found to inhabit the coastal waters of the Sea of Japan, covering from off Akita to Yamaguchi Prefectures, where the next form is confound with this form. But, it should be noticd herewith that the present subspecies could not be collected in the waters along the Pacific, including the Inland Sea of Japan, central region of the East China Sea, and the Tsugaru Strait.

The fishes of this group are very variable, especially in the color and pattern, the spination and other external features, so many ichthyologists have confused them or separated them under various names. If many specimens gathered from various localities are compared externally, everybody may agree to separate the several forms, although sometimes various interconnecting forms within them are found. As the result of my careful study on many specimens, I came to conclusion that the present much ambiguous group of fishes must be separated into two subspecies based on the

following external as well as internal features, thus; i) proportional length of snout; ii) interorbital width relative to snout or eye-diameter; iii) structure of glans clasper; and iv) geographical distribution. Of these, the latter two items were explained elsewhere (c. f. pp. 36, 180), where the present writer has emphasized that the characteristics of the male organ seem to show the most reliable basis for distinguishing the present subspecies from the related one. The differences in other two items mentioned above, however, are not so distinct as to warrant clear-cut demarcation of these two related forms, especially in their youngs. The following is a result of a biometric comparison of some bodily parts of same sex of the two subspecies by using both adult and subadult specimens:

Table 21. Result of t-test for comparison of proportional ratios of snout, eye-diameter and interorbital width in the two subspecies, ♀ ($\bar{X}$) and ♀′ ($\bar{Y}$). Number of specimens used are 7 males and 11 females in ♀, and 11 males and 10 females in ♀′. For other abbreviations, see p. 7.

Items	Mean $\bar{X}$ / $\bar{Y}$	S	t	t_0 (α =0.01)
Snout–length into head–length, male	2.13 / 2.31	0.16	0.13	2.92
....., female	1.84 / 2.01	0.10	2.97	2.97
Eye–diameter into snout–length, male	3.64 / 3.71	0.24	0.60	2.92
., female	4.02 / 3.75	0.51	2.97	2.97
Interorbital width into snout–length, male	3.02 / 3.28	0.26	1.24	2.92
, female	3.47 / 3.28	0.28	2.97	2.97

From Table 21 it may be said that the differences between these two subspecies are significant only in those bodily parts of the female. Conclusively, subspecific demarcations of the two forms in question are found to exist in the structure of male organ, proportional ratios of snout, eye-diameter and interorbital width in female, and difference of their geographical distribution.

Raja (Okamejei) porosa tobae TANAKA
(Abbreviated as ♀′; Japanese, Toba-kasube)
Figs. 78 ♀′ and 79

Raja tobae (*non tobae* TANAKA, 1927) TANAKA, 1917, p. 313 (in Japanese), Toba, Mie Prefecture. —— TANAKA, 1917, p. 453, figs. 353—356, Toba, Mie Prefecture (original description). —— (pars) JORDAN and HUBBS, 1925, p. 111, off Fukui, Sea of Japan; Otaru, Hokkaido. —— FOWLER, 1930, p. 501 (reference). —— MATSUBARA, 1935, p. 45 (key). —— KAMOHARA, 1938, p. 5 , Kôchi. —— FOWLER, 1941, p. 379 (reference). —— ISHIYAMA, 1955, p. 271, figs. 2—4, off Yamaguchi, Inland Sea (electric organ).

Raja porosa ? FANG and WANG, 1932, p. 266, Chefoo, China. —— (pars) MATSUBARA, 1955, p. 137 (key).

Raja meerdervoortii UI, 1932, p. 22, Wakayama, Inland Sea.

Materials examined: 60 specimens (97—495 mm in total length) and 16 egg-capsules from coastal waters of the Pacific and the Sea of Japan; offings of Totoro; Shimonoseki; Senzaki; Yawatahama; Kôchi; Onomichi; Kasumi; Maizuru; Kanaiwa; Chôshi and Funakawa; 1948—1955.

Since the present subspecies closely resembles the foregoing one in both external

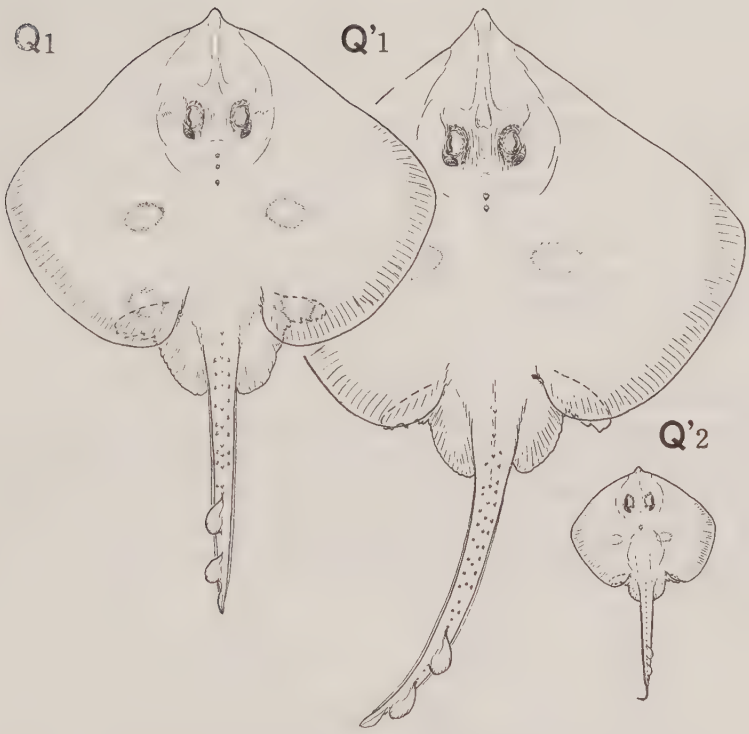

Fig. 78. Comparison of the two subspecies in adolescent and postlarval stages; Q_1, subadult female of *R. porosa meerdervoorti*, (271 mm), from off Kasumi, Hyogo Prefecture; $Q'_{1,2}$, subadult female, (310 mm) and postlarval young of *R. porosa tobae*, (100 mm), from off Yamaguchi Prefecture, the Inland Sea, respectively.

and internal features, and in geographical distribution, the characteristics which will enable us to manifest the present form from the relative may be given here.

External: Snout relatively short, the length relative to head-length different between sexes, being the ratio 2.08 times on average with range from 1.91 to 2.26 (Q′ in Fig. 25); tail short, markedly depressed dorso-ventrally from the root to distal tip, the proportional length to disc-width different between two sexes, being the ratio 1.38 times on average with range from 1.12 to 1.48 (Q′ in Table 7); interorbital space concave, the width apparently greater than eye diameter; interorbital width into snout-length varies from 3.22 to 4.33 times with 3.85 times on average; eye rather small, the diameter into snout length varies from 2.79 to 4.08 times and 3.24 times on average.

Prickles along marginal portion of disc studded in a band, which is somewhat denser than that of the foregoing subspecies when matured, but those setting on nuchal and tail are more or less noteworthy in this subspecies, thus; nuchal spines vary from 2 to 5 and from 7 to 15 in male and female, respectively, and spines on tail not so conspicuously developed in three (male) or five (female) rows, which follow anteriorly a band of minute prickles mesially; two dorsals furnished sparsely with prickles, but pelvic and caudal fins all smooth; ventral side smooth except for a few prickles developed on tip of snout (Fig. 78 $Q'_{1,2}$ and Fig. 79).

Color of dorsal side mottled with various patterns as in case of the relative, and the pectoral ocellus distinct in adult as well as in young stage although it becomes obscure after preservation in formalin; ventral side usually white, excepting some indistinct grayish blotches scattered on central portion of disc and on tail.

Internal: Rostral cartilage rather long, as long as or slightly longer than cranium-length; degree of development of rostral appendices and general form of both anterior and posterior fontanella much the same as in those of the foregoing fish (Fig. 27 Q′). Counts of abdominal and precaudal vertebrae, and of intestinal valves vary in the same extent as in those of the former fish so far as the present investigations go (Q, Q′ in Figs. 43, 44, 48 and Tables 9 and 10); heart valve also numerous, varying from 4 to 6 in a row (Q′ in Fig. 51); electric organ moderate in size as illustrated in Fig. 36 Q′.

Clasper is of Type 9, distinguished from the foregoing subspecies by having relatively longer spike on account of elongated accessory terminal 2 as compared to that in the relative (Q′ in Fig. 5 and 18).

Developmental stages: Increase of thorns on tail begins at a total length of about 300 mm (Fig. Q′ 78), and proportional ratios of snout and tail change with growth of the fish (Q′ in Tables 6 and 7).

Egg-capsule: The capsule somewhat larger than that of the foregoing fish, but capsule-wall having the same structure being composed of two layers without pulpy layer.

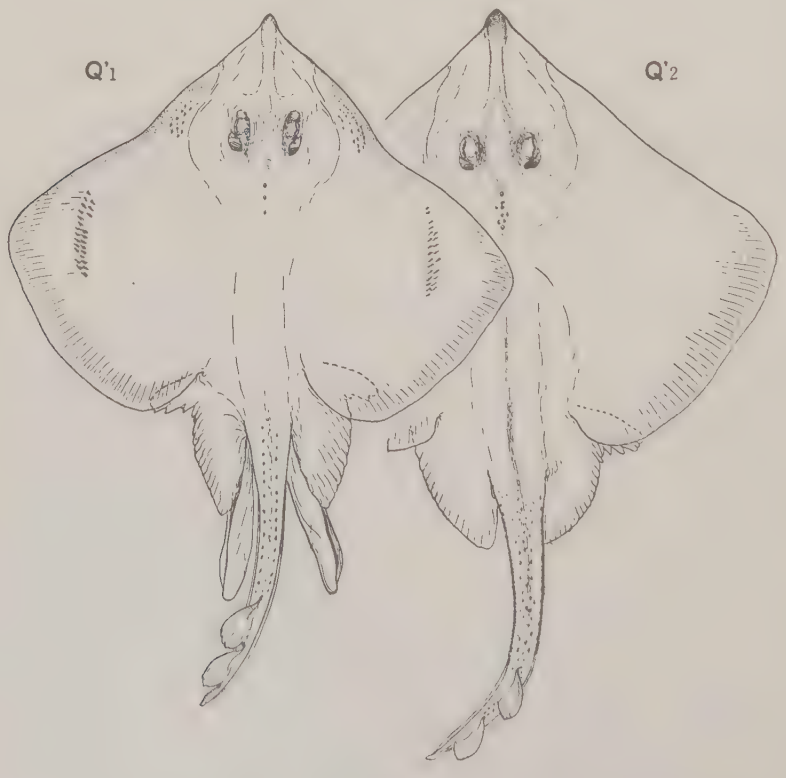

Fig. 79. *Raja porosa tobae* TANAKA; Q′ 1, adult male (450 mm); Q′ 2, adult female (495 mm); from off Yamaguchi Prefecture, the Inland Sea.

Notes: Any workers have met with difficulty in determing whether or not any fish belonging to this group is to be identical with GÜNTHER's *porosa* or JORDAN and FOWLER's *meerdervoorti*, or TANAKA's *tobae*. Thus, the present subspecies and the foregoing one have much the similarity in many respects as has explained repeatedly. But my own examination of a series of specimens involving both the younger and the older fishes taken from various localities listed has succeeded in showing some consistent differences in both external and internal features and in geographical distribution aforementioned. The two subspecies, however, are partly sympatric in their habitat areas along the coastal waters of the Sea of Japan.

Raja (*Okamejei*) *fusca* GARMAN
(Abbreviated as **R**; Japanese name, Kuro-kasube)
Fig. 80

Raja fusca GARMAN, 1885, p. 42, Japan (original description). —— JORDAN and SNYDER, 1900, p. 337, Tokyo (listed). —— JORDAN and FOWLER, 1903, p. 649 (copied). —— PIETSCHMANN, 1908, p. 645, Japan. —— (pars?) JORDAN and HUBBS, 1925, p. 110, Misaki, near Yokohama. —— FOWLER, 1930, p. 501 (reference). —— MATSUBARA, 1935, p. 44, Tokyo (key). MATSUBARA, 1936, p. 24, fig. 15, Tokyo. —— OKADA and MATSUBARA, 1938, p. 24 (key). —— ISHIYAMA, 1950, p. 30, figs. 1 and 2, Chôshi (egg-capsule). —— ISHIYAMA, 1951, p. 629, Chôshi (age-determination). —— ISHIYAMA, 1952, p. 1, fig. 1, Chôshi. —— ISHIYAMA, 1955, p. 271, fig. 4, Chôshi (electric organ). —— MATSUBARA, 1955. p. 137, fig. 21 (key).

Raia fusca (pars) GARMAN, 1913, p. 349, Pl. XX, figs. 4 and 5. Tokyo Bay (holotype).

Raja kenojei (not of MÜLLER and HENLE in part) JORDAN and SNYDER, 1903, p. 652, —— Misaki. —— (pars) JORDAN and FOWLER, 1903, p. 652, Misaki. —— ? PIETSCHMANN, 1908, p. 646, Japan. —— JORDAN and THOMPSON, 1914, p. 208, Misaki. —— (pars) JORDAN and HUBBS, 1925, p. 110, Misaki; Yokohama.

Materials examined: 67 specimens (108—518 mm in total length) and 4 egg-capsules; coastal waters (20—50 m in depth), from off Hachinohe, Aomori Prefecture, to Chôsi, Chiba Prefecture; 1948—1952.

External: Snout very short and blunt, the proportionate length against head not so different between sexes even in adult stage, being 2.2 and 2.1 times on average in male and female, respectively (**R** in Fig. 25 and Table 6). Tail markedly flattened throughout its entire length, the length relative to disc-width also rather same between sexes, measuring 1.4 and 1.5 times on average in the adult of male and female, respectively (**R** in Fig. 32 and Table 7). Membranous folds of tail broad without pigment (Fig. 36 **R**). Interorbital space shallowly concave, the width 2.5—3.0 times in snout-length, and about 1.5 times the diameter of eye, which is rather small. Scales present on dorsum, crowded on anterior portion over rostral axis, anterior-posterior oblique margins of disc, orbital rim, nuchal region, and tail. Of these, those studded orbital rim, nuchal and tail portions are characteristic to the present species, and those growing on anterior marginal region of disc and nuchal portions are different between sexes when matured. Namely, number of orbital spines being respectively 7—9 and 9—13 in male and female; nuchal spines ranging 4—6 in

male and 5—9 in female, followed posteriorly by a broad belt of small prickles continued with three rows of tail spines, which develop in the same manner in the two sexes when matured; in male, anterior marginal portion of the disc opposite the branchial region thickly covered with prickles and malar spines followed posteriorly by a band of alar spines, but in female only the posterior marginal region of disc and distal portion of rostral axis are sparsely furnished with spinous prickles. Two dorsals naked in both sexes even in the adult (Fig. 80 $R_{1,2}$). Ventral surface smooth other than distal portion of snout.

Dorsum deep brown other than snout, scattered with many small black spots, which disapear in preservation. Ventral side white, as a whole, except for distal portion of tail, which is provided with some brown streaks, but in some specimens small brown spots are occasioned.

Internal: Rostral cartilage very short, apparently shorter than cranium; rostral appendix having usual shape as in other species within this genus, the length measuring one-third times the length of rostral bar. Anterior fontanelle triangular in shape, with round corners; the posterior one broadly opened, but with a shallow constriction at the middle portion (**R** in Fig. 27).

Vertebral counts in the two portions respectively 28—29 (28.8 on average) and 39—43 (41.0 on average) (R in Figs. 43, 44 and Table 9). Intestinal valves 7—8, 7.8 on average; valves of conus arteriosus mostly 4—5 (Table 10). Structure of clasper, Type 9, characterized by having elongated spike and rather tapered dorsal terminal 1 (**R** in Figs. 5 and 18).

Developmental stages: Snout-length relative to head-length not so markedly changes with growth of body, especially in female, but in both cases the ratio in head-length becomes greater with age (Fig. 25 **R**). Change of relative length of tail in disc-width with growth of the fish also undiscernible between sexes as explained in Fig. 32. Increase of spines on orbital rim, nuchal and tail regions occur at a total length of about 230 mm (Fig. 80 R_3). It should be noticed that two nuchal spines are found even in the early stage, in most cases (Fig. 80 R_4).

Dorsum darker in adult than in young which having yellowish to brown color and furnished with distinct pectoral ocellus (Fig. 80 $R_{4,5}$).

Egg-capsule: The egg-capsule is of Type 5, moderately large, but the wall is composed of two layers (R_7 in Fig. 80).

Distribution: The present species is found in the waters shallower than 50 meters in depth, ranging from Aomori Prefecture to Tokyo Bay.

Notes: The present species was first recorded by GARMAN (1885) by a very young specimen, 4 3/8 inches in the original description, but 4 3/4 inches in his subsequent record (1913), drawn out from an egg-capsule. PIETSCHMANN (1908) also described based upon a very young female specimen measuring 140 mm in total length. Since all the species referable to the subgenus *Okamejei* closely resemble with each other in the young stage, the identification of this species is by no means easy task based upon the brief description given previously. Having examined many such small specimens taken from near the type locality as those described by GARMAN and PIETSCHMANN, the present author arrived at a conclusion that the present specimens are all referable to the present species on the basis of following facts: i) although four such species as **M**, **P**, **Q′** and **S** are closely related to the present specimens, and although they are found to inhabiting the waters of the type locality of the GARMAN's species and its neighbourings, the two species **M** and **P** are distinguishable from the present

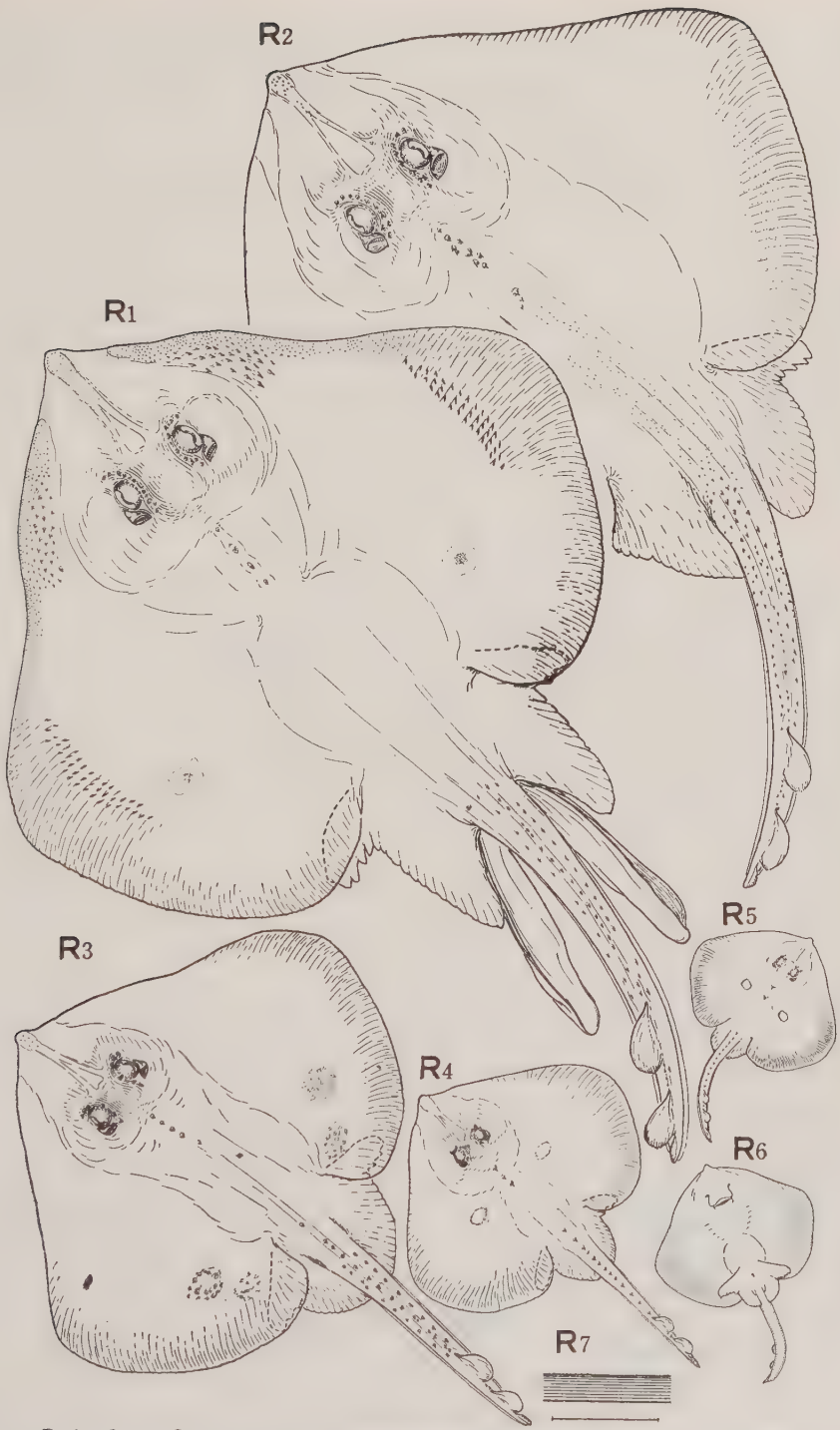

Fig. 80. *Raja fusca* GARMAN R_1, adult male (517 mm, 2—3 ages); R_2, adult female (518 mm, 2—3 ages); R_3, subadult female (325 mm, 1—2 ages); R_4, young female (191 mm, 0—1 age); $R_{5,6}$, dorsal and ventral aspects of postlarval young male (118 mm, 0—1 age); R_7, section of egg-capsule, scale 1 mm; from off Chôshi, Chiba Prefecture.

specimens in having unique color pattern or in lacking pectoral ocellus even in the early stage; ii) in comparison of the present specimens with those of ♀′ and ♂ as well as the present specimens in description with this species given by GARMAN, it was found that the present specimens are more closely fitted with GARMAN's species than either ♀′ or ♂.

The present author agrees with the opinion given by JORDAN and HUBBS (1925) that "the form identified by recent workers as *R. kenojei* is the adult of *Raja fusca*, ...", but their identification of the fish taken from the Toyama Bay, being referred to the present species, is doubtful inasmuch there is no reliable record of the occurrence of the present species from the Japan Sea so far as the present author is aware.

SCHMIDT's (1931) description of this species will be discussed with annexed species.

The present author has given an account (1951), where he has dealt with the method of age-determination of the present species, and made clear the annual growth of the fish (cf. p. 120 in this article and Fig 80).

Raja (*Okamejei*) *schmidti*, n. sp.

(Abbreviated as ♂; Japanese name, Tsumari-kasube)

Fig. 81; Pl. III, ♂

Raia kenojei (non MÜLLER and HENLE, 1841) GARMAN, 1913, p. 349, pl. XXIV, figs. 1 and 2. Izu Sea, Shizuoka Prefecture.

Raja kenojei (pars) FOWLER, 1940, p. 372 (reference). —— (pars) HERRE, 1953, p. 39 (listed).

Raja fusca (non GARMAN, 1885) SCHMIDT, 1931, p. 11, figs. 2 and 3, Tokyo Bay.

Materials described: Holotype, 507 mm, off Ehime Prefecture, Bungo Strait, March 20, 1950; paratypes, 39 specimens (162—523 mm in total length) and 4 egg-capsules, from off Totoro, Miyazaki Prefecture; Yawatahama, Ehime Prefecture; Miya, Aichi Prefecture; 1948—1953.

External: Disc-width 1.58, disc-length 1.91, tail 1.88, head 3.72 in total length; head 2.35, snout 5.71, precaudal 1.74 and procaudal 3.76 in disc-width; interobital width 2.73, eye-diameter 2.94, longer axis of two dorsal fins 1.33, and caudal 2.94 in snout, respectively.

Snout very short, pointed anteriorly; anterior margins on two sides of disc strongly undulated. Interorbital space concave, 1.05 times as wide as eye-diameter, which is rather large. Tail rather flattened, as long as disc. Two dorsals large, the longer axis much longer than interorbital width; caudal fin small; ventral incision moderately deep. Clasper stout, extending posteriorly as far as the midway point of tail.

Body almost naked with exceptions of anterior marginal region, orbital rim, nuchal and tail regions as usually found in the relatives, viz., minute prickles covering both surfaces of distal part of snout and anterior oblique region of dorsum of disc, which is also furnished with patches of malar and alar spines; 9 enlarged spines setting on each orbital rim; only one spine present on nuchal region; an irregular row of spines running along mesial line of tail, which is strengthened by a row of spines on left side and two rows of similar ones on rim; very small prickles covering dorsals (Fig. 81 S_1).

Color yellowish brown with many dark-brown spots, which are densely crowded on middle belt, but large and sparsely set on head. Pectoral ocellus present in fresh condition, but disappeared after preservation. Ventral side faint gray in main portion of disc excepting marginal band with pale purplish brown; ventral side of tail and

pelvic fin whitish (Pl. III, S).

Internal: Rostral cartilage very short, much shorter than cranium; rostral appendix shorter than half the length of rostral cartilage; both anterior and posterior fontanella broadly opened, the anterior one pointed at anterior tip (Fig. 27 S). Electric organ less developed, but reaching ateriorly as far beyond posterior extremity of pelvic fin (Fig. 37 S). Precaudal vertebrae 27—29 (28.0 on average); procaudal vertebrae 42—45 (43.4 in average) (S in Figs. 43, 44 and Table 9).

Intestinal valves, mostly 7; valves of conus arteriosus 4 in many cases, (S in Tables 10 and 11).

Structure of clasper is of Type 9, distinguished from that of relatives in having lesser produced spike and broadly developed dorsal terminal 1 (S in Figs. 5 and 18).

Of descriptions mentioned above, those on external features were given from the holotype, but those on internals were derived from paratypes, based on which the followings are supplemented.

Length of snout relative to head-length gradually reduced with growth of the fish, being the ratio into head-length increases from about 2.0 times or more large

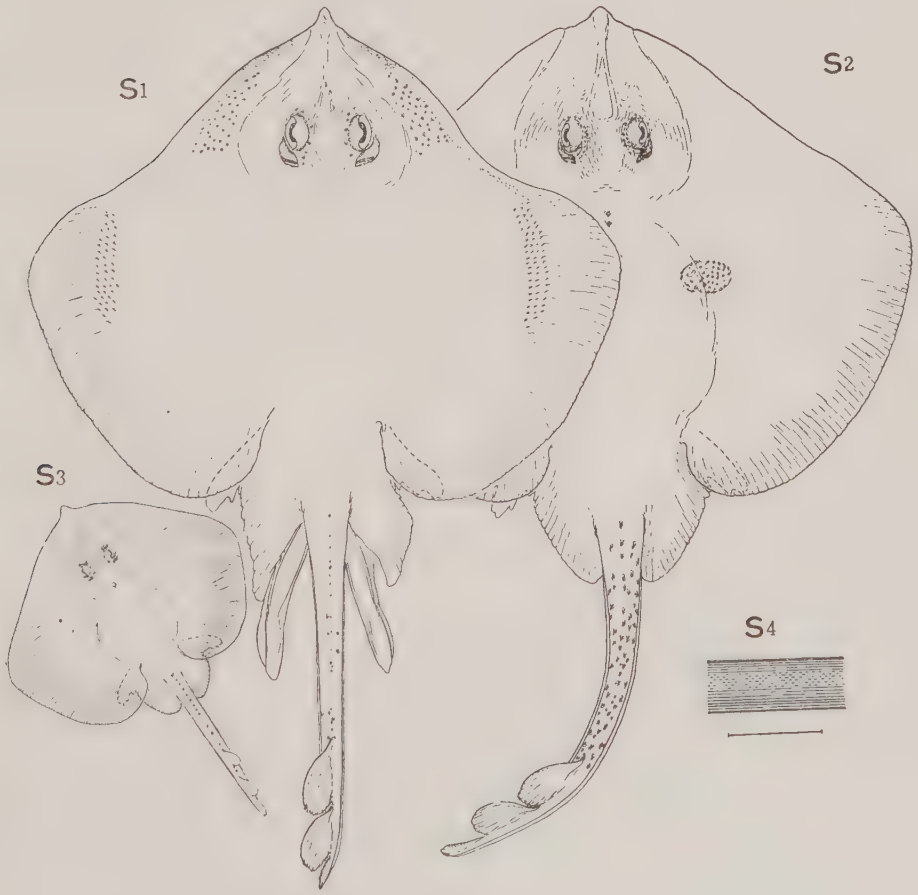

Fig. 81. *Raja schmidti*, n. sp.; S_1, holotype, adult male (507 mm); S_2, adult female (521 mm); S_3, young male (198 mm); S_4, section of egg-capsule, scale 0.5 mm; from off Ehime Prefecture, Bungo Strait.

up to about 2.2 (female) or 2.4 (male) times (**S** in Fig. 25 and Table 6). Conversely, relative length of tail against disc-width decreased in small extent with the growth of the fish, discriminating between two sexes (**S** in Fig. 32 and Table 7).

Developmental stages: Spination in the young is revealed with the same tract as in many of the southern forms, viz., three spines on orbital rim, one on nuchal, and a row with 12—14 spines on tail. These downy prickles begin to increase when the fish attains to total length of about 250 mm. In the adult, supraorbital and nuchal spines cover from 4 to 13, mostly 6 and from 1 to 3, mostly 1, respectively, and tail of the female is marked by having irregular rows of spines (**S** in Fig. 37).

Color of dorsum in the young orange brown and furnished with distinct dark brown pectoral ocellus which enclosing some 4—6 brown spots, but the ocellus disappears or becomes obscure in the adolescent, in most cases, in turn for the development of deep brown spots on the surface. The ventral side in the young with similar hue as in the adult.

Egg-capsule: Egg-capsule is moderate in size with similar appearance to that of species **R**, but the two are distinguished from each other by having different structure of the capsule-wall. The wall composed of three layers inserting a pulpy layer in the present species (Fig. 81 S_4), but two layers in the other (cf. Fig. 80 R_7).

The present species is confined to the coastal waters shallower than 50 meters in depth, ranging from the Tokyo Bay to southern extreme of Kyusyu except for the regions facing the Japan Sea and the Inland Sea (Fig. 1).

Remarks: The present species was first described by GARMAN (1913) erroneously as *Raja kenojei* from a specimen taken by Alan OWSTON from the Izu Sea, offing Sizuoka Prefecture. SCHMIDT (1931) also erroneously referred the specimens corresponding to the present species to *R. fusca*, with a view to supplement the original description that has been given briefly based upon a young specimen. The present species is sharply defined from an allied species, *R. fusca*, in the following points:

	fusca	*schmidti*
1. Interorbital width	much greater than eye-diameter.	almost as great as eye-diameter.
2. Snout, from upper lip	much longer than width of mouth.	slightly longer than width of mouth.
3. Longer axis of 1st D.	triffle longer than interorbital width.	much longer than interorbital width.
4. Two dorsals	naked.	prikled.
5. Nuchal spine	4—6 in adult male	1—2 in adult male.
6. Ground color of dorsum	deep brown.	yellowish borwn.

The present species may be a derivative sprung off from a specialized form like form not very unlike the species **R**, since the present species has more advance features in such parts as snout and clasper than the latter, and the two species are found to inhabit with a boundary near Tokyo Bay, viz., the present species is found southern region from the boundary to the extreme south of Kyusyu, but the latter ranges northern waters from the boundary to the extreme north of the main island of Japan, on the Pacific coast.

*Tengujei**), n. subg.

The characteristics of the present subgenus are in relatively long snout, tail furnished with spines (one row in male and three or five rows in female) and electric organ developed in greater or moderate degree, numerous counts of precaudal vertebrae and clasper established in related features with much specialized or rather simple structure. In Japanese rajids, the following four species are referable to the present subgenus, and are all large in size of the body and the egg-capsule.

Type species: *Raja tengu* Jordan et Fowler, 1903.

It is of much interest to note that a considerable number of species having such similar features in general appearance as to the Japanese species are found to exist in both the Pacific and the Atlantic and its neighbourings, such as *Raja rhina*, *R. binoculata* in the north western Pacific, and *R. batis* and *R. oxyrhynchus* in the Atlantic. In this connection, although assumtive it may be, the present subgenus appears to have a congeneric origin with those which may be found in the north western Pacific and the Atlantic.

Key to species of the subgenus *Tengujei*

1a. Precaudal vertebrae fewer than 50, varying from 38 to 50; glans clasper is of Type 11 or 12, rather simple or much specialized; electric organ moderately developed even in adult.

2a. Precaudal vertebrae 46—50, 47.6 on average; spiral valves of intestine 9—11, 10.1 on average; glans clasper is of Type 11; snout narrowly elongated; tail relatively long, slender and rod-like form in its main portion, having one row of spines in male, but three rows in female when matured; color uniformly grayish brown on dorsum without pectoral ocellus ..... *tengu* (Figs. 82 and 84 **T**)

2b. Precaudal vertebrae 38—42, 39.1 on average; intestinal valves 14—15, 14.5 on average; glans clasper is of Type 12, much specialized in structure; snout broadly elongated; tail relatively short and depressed, armed with a row of spines in male, but five rows in female when matured; dark brown blotches numerous on dorsum with distinct pectoral ocellus ..... *pulchra* (Figs. 83, 84 **U** and pl. III, **U**)

1b. Precaudal vertebrae more than 50, varying from 53 to 61; glans clasper is of Type 13, characterized by having rather complex structure; electric organ highly developed.

3a. Precaudal vertebrae 53—59, 55.3 on average; ventral incision rather shallow; dorsal surface smooth in young, excepting those spines on orbital rim and tail; thorns on tail of adult female poorly developed; both surfaces of body lead-gray without pectoral ocellus ..... *macrocauda* (Figs. 84 **V** and 85)

3b. Precaudal vertebrae 59—61, 60.0 on average; ventral incision remarkably deep; dorsal surface entirely setose with minute prickles in addition to tracts of spines developed in the young; thorns on tail of adult female much thickened, running in three rows; both surfaces of body blackish gray without pectoral ocellus .... *gigas*, n. sp. (Figs. 84 **W** and 86).

Raja (*Tengujei*) *tengu* Jordan et Fowler
(Abbreviated as **T**; Japanese name, Tengu-kasube)
Figs. 82, 84 **T**

Raja tengu Jordan et Fowler, 1903, p. 654, fig. 8, Matsushima Bay, Miyagi

* Named from *Tengu* in Japanese mythology, a long-nosed goblin, and from *jei*, meaning a skate and ray in Japanese, i. e. long-nosed skate.

Prefecture; Aomori; Hakodate (original description). —— JORDAN and STARKS, 1904, p. 578, Matsushima Bay (listed). —— JORDAN and HUBBS, 1925, p. 110 (key). —— FOWLER, 1929, p. 501 (reference). ——? SOLDATOV and LINDBERG, 1930, p. 20, Pl. 1. —— MATSUBARA, 1935, p. 30 (key). —— OKADA, UCHIDA and MATSUBARA, p. 59, pl. 10. —— MATSUBARA, 1935, p. 45, fig. 20. —— TARANETZ, 1935, p. 89 (reference). —— OKADA and MATSUBARA, 1938, p. 25 (key). —— FOWLER, 1941, p. 361, northern Japan. —— ISHIYAMA, 1955, p. 271, figs. 2—4, off Kasumi, Japan Sea (electric organ). —— MATSUBARA, 1955, p. 137 (key). —— TANAKA and ABE, 1955, p. 27, fig. 61.

Raia tengu GARMAN, 1913, p. 355 (compiled).

Materials examined: 51 specimens (185—1130 mm in total length) and 2 egg-capsules; moderate depth off from Otaru, Hokkaido to Totoro, Miyazaki Prefecture; 1947—1955.

External: Snout very long and acuminated, being concave with more or less undulation on both sides, and relatively shorter in male than in female, covering 1.7 times in head-length in male, but 1.6 times in female in the adult (T in Fig. 25 and Table 6). Tail reltaively long, stiffened with roled appearance in its main portion, relatively somewhat longer in male than in female, being about 1.6 times in disc-width in male and 1.7 times in female in the adult (T in Fig. 32 and Table 7). Inter-orbital space broad and flat, the ratio of width in snout-length variable even in the adult, ranging from 4.3 to 5.3 times. Eye very small relative to broad interorbital space, the ratio being 1.0—1.8 times in the latter.

Anterior marginal portion of the dorsum and entire ventral surface of head of the adult are studded with prickles; somewhat enlarged thorns placed irregularly along orbital rim; usually only one, but occasionally two to four, large nuchal spines present; a row of about 20 to 40 spines runs along mesial line of tail in adult male, intermitted by an intervention of 1st dorsal fin, but the spines are running in three rows inclusive of those on sides of tail in matured female, (Type-Sc^{SA}); two dorsal fins prickled more or less in both sexes; alar and malar spines also distinct when the fish attains to its maturation, as is the case with other species, (Figs. 82 and 84 T).

Color of dorsal surface uniformly brown in usual case, but it is somewhat lighter in ventral side, and occasionally very obscure patterns of dark color are developed on both sides when fresh.

Internal: Rostral cartilage very long and stout, about 1.5 times as long as cranium-length; rostral appendix also long and distinct, covering about the half length along the side of rostral cartilage; anterior fontanelle very long, posterior one constricted at the middle portion (Fig. 27 T).

Abdominal and precaudal vertebrae 31—32 and 46—50, respectively (T in Figs. 43, 44 and Table 9). Intestinal valves 9—11 (Table 10). Heart valves 4—5 in a row. Electric organ moderately developed occupying of whole length of tail on both sides (Fig. 37 T).

Clasper is of Type 11, characterized by having rather simple structure as compared with those of the relatives (T in Figs. 6 and 19).

Developmental stages: Snout long and narrowly elongated even in very young stage (Fig. 84 T), and the length relative to head is unchanged with growth in male instead of becoming somewhat longer in female (Fig. 25 T). Tail relatively longer in young than in adult, being gradually increased with growth of the fish its ratio to

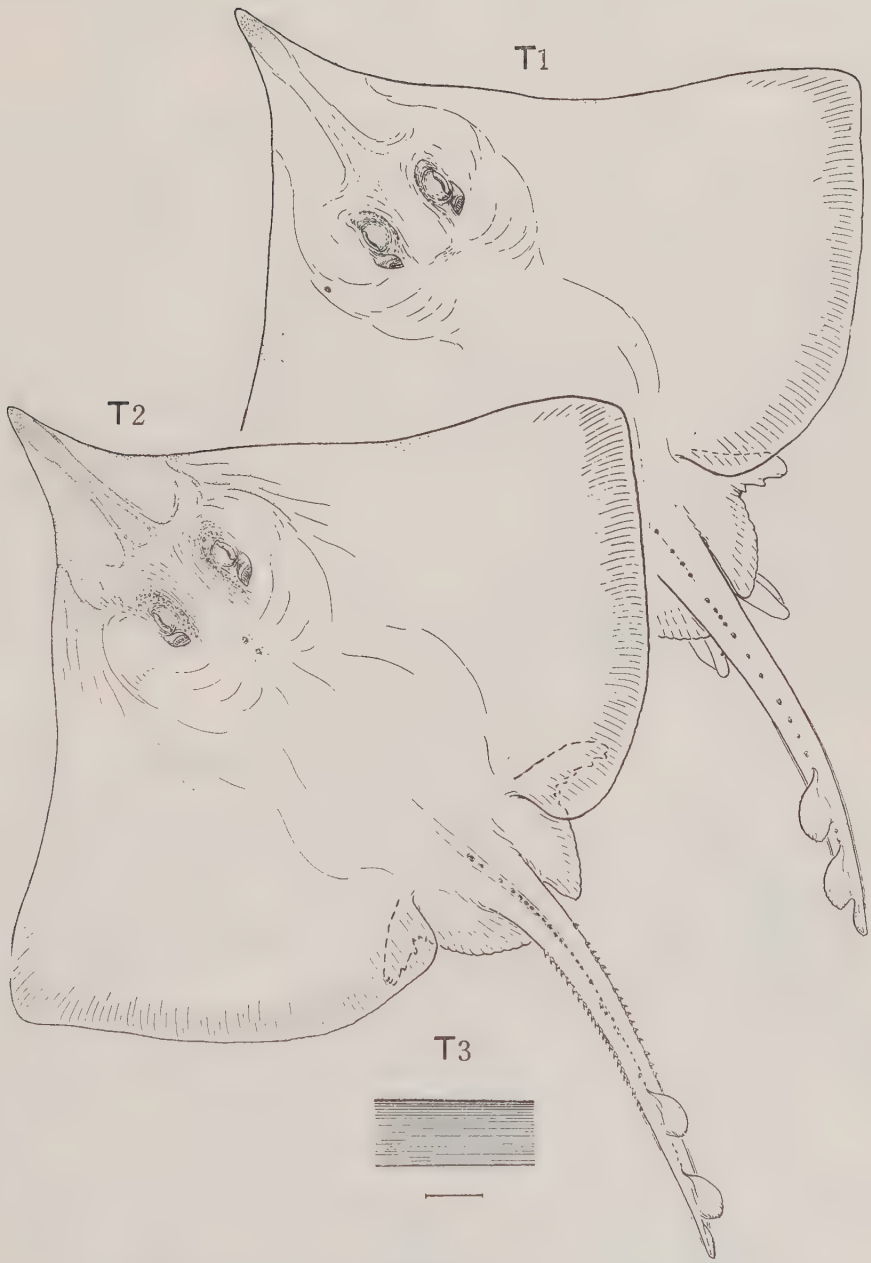

Fig. 82. *Raja tengu* JORDAN et FOWLER; T_1, adult male (728 mm) T_2, adult female (920 mm); T_3, section of egg-capsule, scale 1 mm; T_1, from off Totoro, Miyazaki Prefecture; $T_{2,3}$, from off Aichi Prefecture.

disc-width in both sexes (Fig. 32 T). Relative length of both snout and tail thus change in adolescent stage, attaining from about 200 to 400 mm of disc-width. Newly hatched young armed with a series of 13 to 15 spines on tail and one on nucha and three on orbital rim as in case of other members of the southern form.

Color on both sides of body yellowish brown without any color patterns in young stage.

Egg-capsule: Rather large, about 100 mm in length exclusive of horns; the horn is short and tube-like form; surface very smooth; capsule-wall composed of three layers, being inserted very thin pulpy layer. On the basis of these characteristics the capsule of this species is referred to Type 6 as explained elsewhere, (Fig. 82 T$_6$).

Notes: The present species is found from northern region of the Japanese waters to the East China Sea, throughout the waters on both sides of the shelf around Japan except for the Sea of Okhotsk. It lives in the moderate depth, covering from about 60 meters (in northern regions) to 100 meters or more below (in southern waters).

This species is by no means confused with other relatives of Japanese rajids, by having much longer, slenderer snout and having unique features of the spination especially in the adult. A comparison of the young with those of the relatives in Japanese rajids will be dealt with the following species, which resemble more or less the present species in general faces. In these characteristics the present species is closely related to the European species, *R. oxyrynchus*. But the present species can be distinguished from it in having relatively shorter snout when compared the same sized fishes of the two. Namely, the snout is contained 2.9 times into disc-width and the former 5 to 6 times as long as or a little longer than interorbital width in European species (disc-width, 778—994 mm), but the ratios are 3.2 to 3.7 times and 4.3 to 5.7 times, respectively, in the present species of similar size.

Raja (*Tengujei*) *pulchra* LIU

(Abbreviated as U; Japanese name, Megane-kasube)

Figs. 83, 84 U; Pl. III, U

Raja smirnovi JORDAN and HUBBS (non SOLDATOV and PAVLENKO), 1925, p. 111, off Fukui and Otaru. —— FANG and WANG, 1932, p. 262, fig. 21 , Chefoo, China. —— MATSUBARA, 1935, p. 45 (key). —— MATSUBARA, 1936, p. 27, fig. 18 (reference). —— OKADA and MATSUBARA, 1938, p. 24 (key). —— LIN, 1955, p. 30, fig. 22. North China. —— SATÔ and KOBAYASHI, 1955, p. 1, Volcano Bay, Hokkaido.

Raja tengu FOWLER, 1941, p. 361 (reference).

Raja pulchra LIU, 1932, p. 162, fig. 10, Tsingtao (original description). —— ISHIYAMA, 1950, p. 30, figs. 1 and 2, Wakkanai, Hokkaido (egg-capsule). —— ISHIYAMA, 1954, p. 75, figs. 1—3, Hokkaido (electric organ). —— ISHIYAMA, 1955, p. 43. —— ISHIYAMA, 1955, p. 271, fig. 4 (electric organ). MATSUBARA, 1955, p. 136 (key).

Materials examined: 89 specimens (150—1119 mm in total length), 20 embryos, and 25 egg-capsules; from shallow waters off Hokkaido to moderate depth of the East China Sea; 1947—1954.

External: Snout broadly elongated, different between two sexes in relative length, being the ratio into head length 1.95 times on average in adult male as compared with 1.72 times on average in adult female (U in Fig. 25 and Table 6). Tail relatively short, Depressed-type, being the average ratio into disc-width 1.57 times in adult male

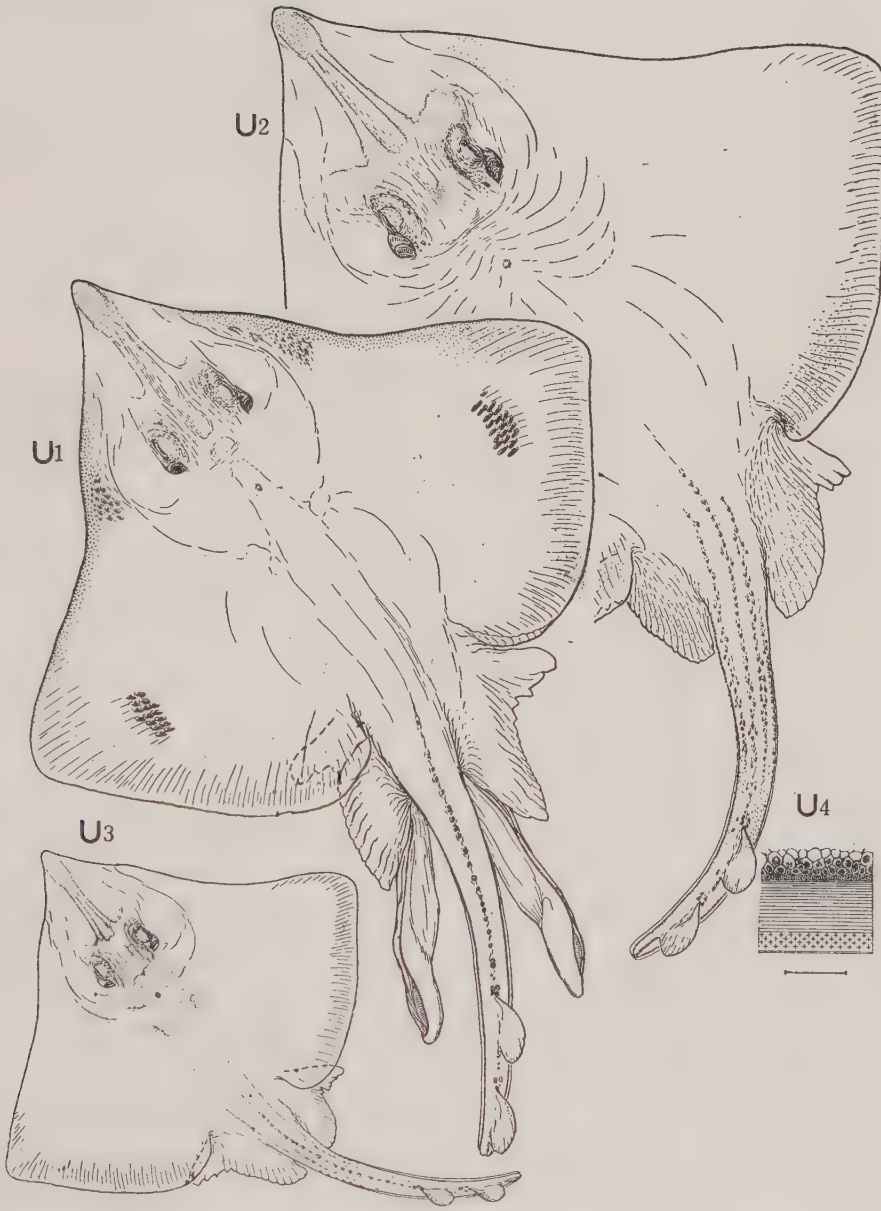

Fig. 83. *Raja pulchra* LIU; U_1, adult male (1052 mm); U_2, adult female (1119 mm); U_3, subadult female (606 mm); U_4, section of egg-capsule, scale 0.5 mm; $U_{1,2,3}$, off Wakkanai, Hokkaido; U_3, off Monbetsu, Hokkaido, the Okhotsk Sea.

and 1.71 times in adult female (U in Figs. 30, 32 and Table 7). Interorbital space broad, flat, and the width relative to length of snout about 3.3 and 3.6 times respectively in male and female when matured. Eye rather small, the average ratio into snout-length about 5.6 and 8.5 times, respectively, in adult of male and female. Caudal fin very small or eventually reduced into rudimentary.

Prickles develop in adult fish on anterior marginal portion of head as in the species T, but absent on ventral surface except for distal and mesial portions of the snout; a series of enlarged spines closely covering each orbital rim; a large nuchal spine present without exception; a row of large spines setting along mesial line of tail in adult male, but five rows in the female (Type-Sc^{SB}); two dorsals sparsely prickled in both sexes (Fig. 83).

Color of dorsum mottled with dark brown irregular patterns, and the pectoral ocellus more or less well-developed, but occasionally obscure in the adult; ventral surface of disc usually white without any color patterns, but on the tail a few brown streaks present in some cases (Pl. III, U).

Internal: Rostral cartilage long and stiffened especially in its basal portion, and the length into cranium-length about 1.5 times; rostral appendices small, reduced into one-fourth the length of rostral cartilage or shorter; anterior fontanelle distinct, elongated anteriorly with shallow furrow, posterior one divided into two hollow by an intervention of a narrow cartilaginous bridge (Fig. 27 U).

Abdominal and precaudal vertebrae 30—32 and 38—42, respectively (U in Figs. 43, 44 and Table 9). Intestinal valve thickened, more numerous than in any of the relatives, varying from 14 to 15 (U in Figs. 47, 48 and Table 10). Heart valves mostly 8 in a row (U in Fig. 51 and Table 11).

Electric organ relatively small, lying from distal tip to base of pelvic fins (U in Figs. 30 and 37).

Clasper very large (Fig. 83), and much specialized in both external and internal features, being marked as the organ of Type 12 (U in Figs. 6 and 19).

Developmental stages: Snout relatively short and somewhat flexible in young fish (Fig. 84 U) immediately after emerged from the egg-capsule, but it becomes longer and stouter when the fish attains to above 100 mm or more in width of disc and discernible the difference of relative growth between two sexes (Fig. 25 U). Length of tail relative to width of disc markedly changes with growth of the body, discriminating between sexes when matured, being relatively longer in female than in male as in case of the preceding species T, (Fig. 32 U). Caudal fin gradually reduced its relative size with age, though it is distinct in the young (U in Figs. 30 and 34). Newly hatched larva armed only with a series of 9—12 spines on tail, 3 spines on orbital rim, and one large spine on nucha (Fig. 84 U), but the spines on tail become to increase when the fish attains to about 100 mm in width of disc (Fig. 83 U_3).

Color and pattern of dorsum in developmental stages are similar to as in the adult, as a whole, but the pectoral ocellus very distinct in the young; ventral surface white as in the case of the adult.

Egg-capsule: The egg-capsule is peculiar (Type 8), in having rectangular outline with deep notches on middle portion of lateral sides, and having short flattened horns on anterior and posterior corners, and remarkable capsule-wall belonging Type-Eg^{7} (Fig. 83 U_1). The capsule is usually enclosing more than one egg, varying from one to five.

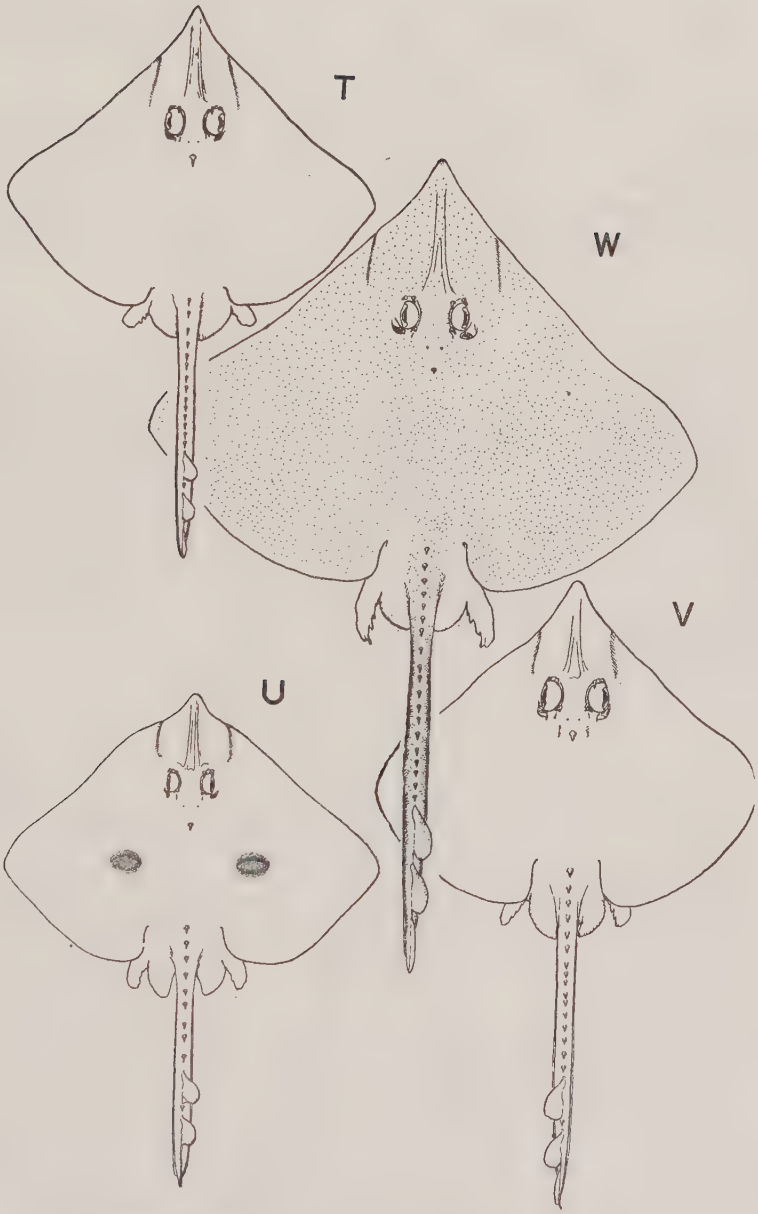

Fig. 84. Comparison of four species in young stage; T, *R. tengu*, female (211 mm); U, *R. pulchra*, female (78 mm); V, *R. macrocauda*, male (238 mm); W, *R. gigas*, male (312 mm); T, W, from off Totoro, Miyazaki Prefecture; U, off Monbetsu, Hokkaido; V, off Miya, Aichi Prefecture. All these fishes are in the same stage in life history.

Notes: The present species ranges from the Sea of Okhotsk to the East China Sea, throughout the shelf of both the Pacific and the Sea of Japan, especially abundant in the coastal waters around Hokkaido, where the present fish is important commercially as its "dried fish" is sold in considerable quantities, the so-called as "Hoshi-kasube" in Japanese. It is usually caught in the coastal waters covering from about 30 meters (the Sea of Okhotsk) to 80 meters (offing from middle region of the main island of Japan to the East China Sea) in depth.

Since JORDAN and HUBBS (1925) and FANG and WANG (1932) misidentified this species taken from the Sea of Japan and the China Sea as *Raja simirnovi* SOLDATOV et PAVLENKO Japanese ichthyologists has followed this identification without any criticism. But the present author (1950) has confirmed that *Raja smirnovi* of JORDAN and HUBBS and of FANG and WANG is quite different from that of SOLDATOV and PAVLENKO (1915), and that in fact it is identical with *Raja pulchra* given by LIU in 1932.

The present species resembles the species **T** and **V**, in having some important characters, such as longer snout, spination in adult male, number of vertebrae and structure of clasper. On the basis of these characteristics, the present species is supposed to be a shallow-water representative that may have specialized from an ancestor like the species **T**. Several species have been known from both the Atlantic and the north western Pacific which somewhat resemble the present species in general appearance, in having broadly elongated snout and largely smooth dorsal surface with mottled color pattern as in such species as *Raja batis* found in the Atlantic, *R. rhina* and *R. binoculata* from the north Pacific, and *R. flavirostris* from the South American waters of the Atlantic. But the present species is endemic in the waters around Japan though these relatives seem to be congeneric descendants.

Raja (*Tengujei*) *macrocauda* ISHIYAMA
(Abbreviated as **V**; Japanese name, Kitsune-kasube)
Figs. 84 **V**, 85

Raja oxyrinchus MATSUBARA (non Linnè), 1936, p. 30, fig. 22, Kôchi fish market. —— OKADA and MATSUBARA, 1938, p. 25 (key). —— KAMOHARA, 1938, p. 10, Kôchi. —— KURODA, 1952, p. 7, SURUGA Bay.

Raja macrocauda ISHIYAMA, 1955, p. 43, figs. 1 and 2, off Aichi Prefecture, Kumano-nada (original description). —— ISHIYAMA, 1955, p. 273, figs. 2—4 (electric organ). —— MATSUBARA, 1955, p. 136, off Aichi Prefecture (key).

Materials examined: 37 specimens (189—1250 mm in total length) including holotype, deep seas offing from Totoro, Miyazaki Prefecture to Chôsi, Chiba Prefecture; 1950—1955.

On this species, a detailed description has been given in the previous report (ISHIYAMA, 1955), where both the external and internal features of the present species as well as relationship in the relative forms were given. In this account, therefore, only the characteristics other than those given in the previous report will be mentioned.

Clasper is of Type 13, characterized by having specialized accessory terminal 2 (**V** in Figs. 6 and 19). It may be sure to consider that the present species is intermediate between species **T** and **W**, and that the species **W** is nearer than **T** to the present species. Comparison between the present species and related ones will be shown precisely later on.

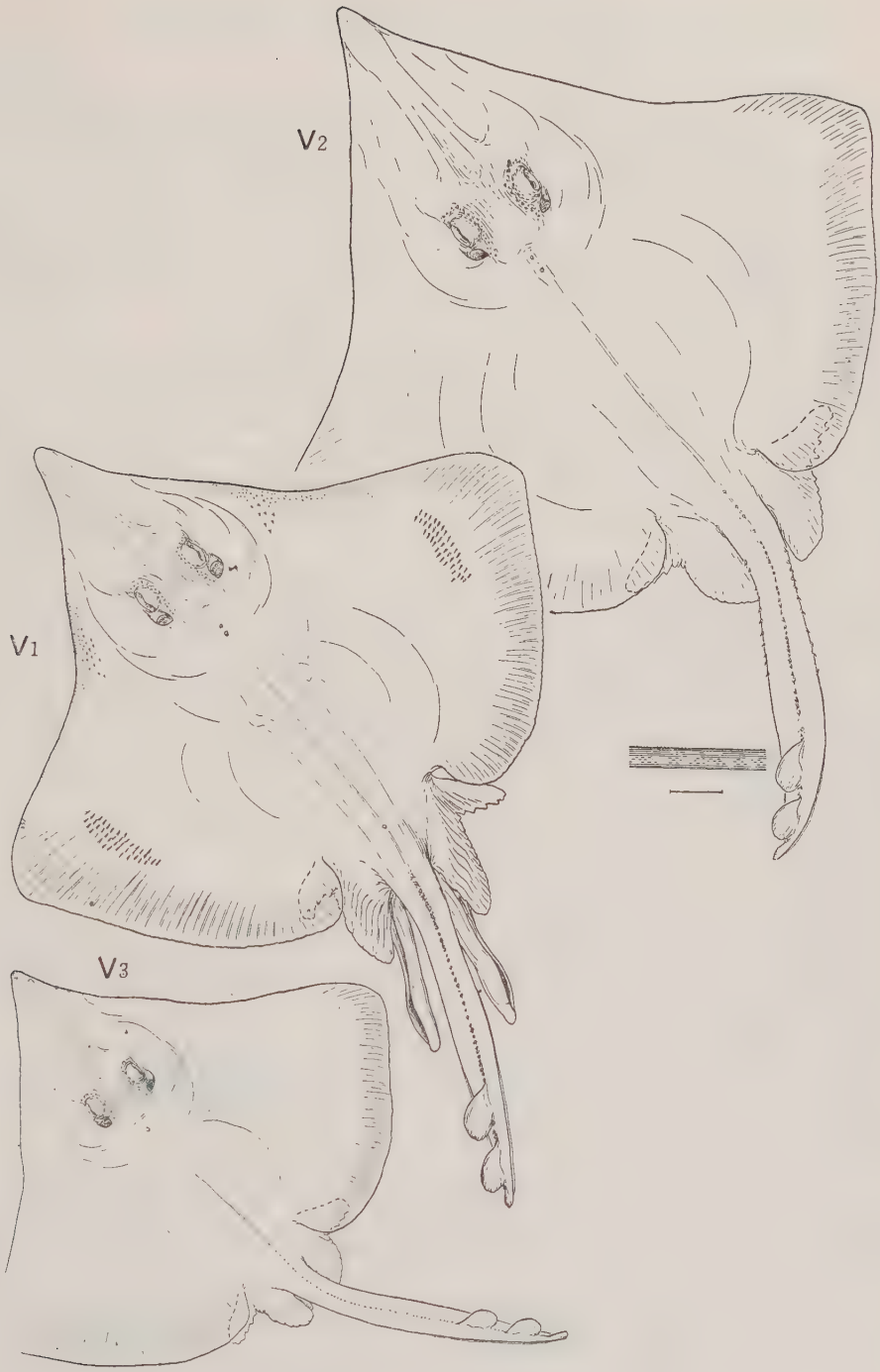

Fig. 85. *Raja macrocauda* ISHIYAMA; V_1, holotype, adult male (997 mm); V_2, adult female (1088 mm); V_3, subadult male (745 mm); V_4, section of egg-capsule, scale 1 mm; from off Miya, Aichi Prefecture.

Raja (Tengujei) gigas, n. sp.
(Abbreviated as **W**; New Japanese name, Zô-kasube)
Figs. 84 **W**, 86

Materials described: Holotype, 1345 mm, off Aichi Prefecture, Kumano-nada, March 27, 1955; paratypes, 20 specimens (313—1860 mm in total length) and 2 egg-capsules, off Totoro, Miyazaki Prefecture; Miya, Aichi Prefecture; Maisaka, Shizuoka Prefecture: 1954—1955.

External: Disc-width 1.34, disc-length 1.72, tail 2.11 in total length; head 2.24, snout 4.16, precaudal 1.10 and procaudal 4.87 in disc-width; interorbital width 3.58, diameter of eye 6.66, lengths of both dorsal fins 3.03, and that of caudal 3.22, ventral incision 2.52 in snout.

Snout long, broadly elongated anteriorly, having a stout rostral axis, with anterior oblique margins strongly undulated. Interorbital space broad and flat, the width much greater than eye-diameter, which is 1.86 times into the width. Anterior lobe of pelvic fin markedly elongated, inserting very deep notch between it and the posterior lobe. Clasper very large and stout, reaching midway point of tail. Membranous fold along the sides of tail distinct, extending from the basal portion to the tip.

Body almost smooth on both surfaces excepting the annexed portions, which are furnished with thorns and spinules, thus; anterior and posterior oblique marginal portions of dorsal side of disc covered with either minute or enlarged prickles, or the both of them, and mesial portion of rostral axis on ventral side also prickly; a number of thorns scattered on orbital rim of each eye; nuchal spine obscure due to worn out being in mature; a patch of the alar spines robustly developed; a row of large spines setting along mesial line of tail, some of which are distinct but others more or less illegible owing to worn out as is the case with the nuchal spines (Fig. 86).

Color of dorsum uniformly gray or blackish gray without pectoral ocellus; the ventral side of the body blackish gray.

Internal: Rostral cartilage very long and stout, inserted anteriorly by a pair of rostral appendices fused throughout their whole lateral edges with the sides of rostral bar, as in the relatives; the bar is about 1.5 and 1.3 times as long as cranium-length and cranium-width, respectively, and is about 2.4 times the length of rostral appendices. Anterior fontanelle distinct, leaf-like in shape, followed anteriorly by excavated portion; posterior one also large, ellipsoid in outline (Fig. 26 **W**).

The electric organ well-developed, bluntly pointed anteriorly and gradually becomes slenderer posteriorly, extending from the basal portion to the tip of tail (**W** in Figs. 37 and 40).

Abdominal and precaudal vertebrae more numerous than in any of the southern members, varying from 30 to 34 and from 59 to 61, respectively (**W** in Figs. 43, 44 and Table 9). Intestinal valves 10 or 11; heart valves 4 in a row (**W** in Tables 10 and 11).

Clasper is of Type 13, characterized by having much specialized accessory terminals 1 and 2 (W in Figs. 6 and 19).

The above description on external features was derived from the holotype (matured male) measuring 1345 mm in total length, but those on internal ones were taken from the paratypes. The followings are supplemented in making clear diagnosis of the present species, based on many specimens involving younger and also older fishes, and

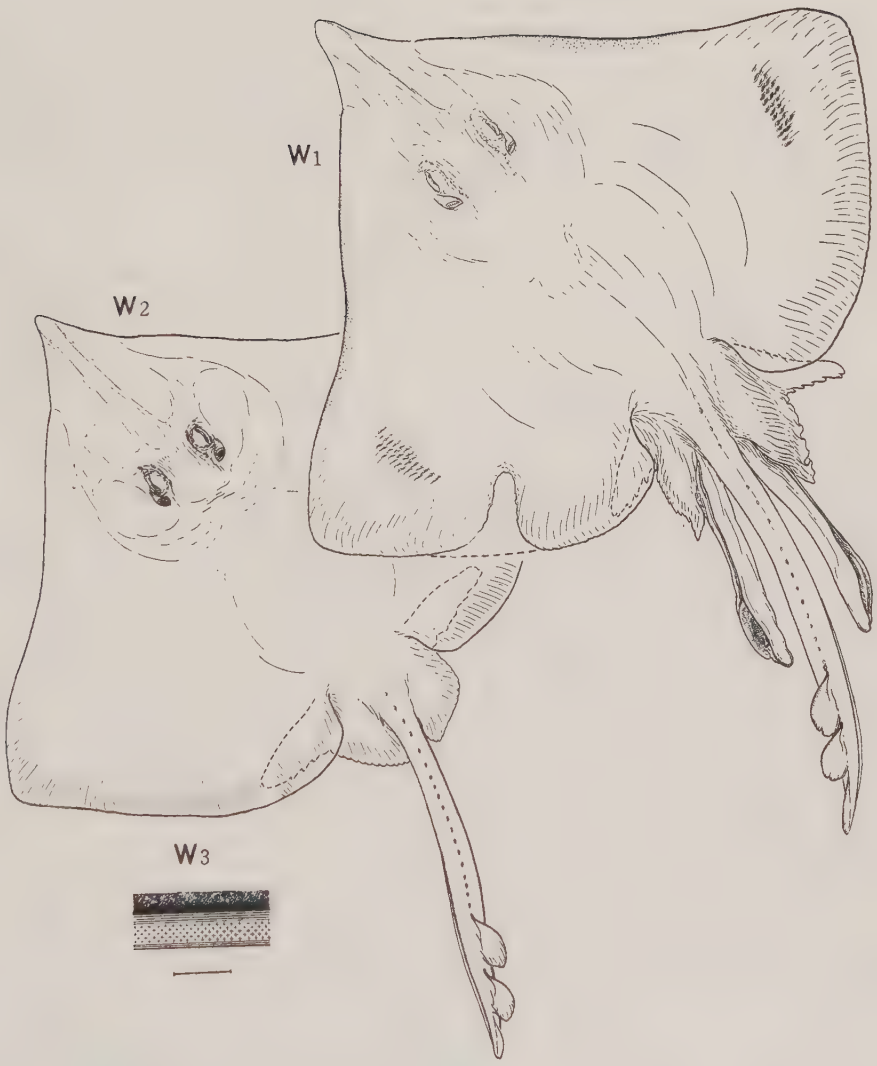

Fig. 86. *Raja gigas*, n. sp.; W_1, holotype, adult male (1345 mm); W_2, subadult female (945 mm); W_3, section of egg-capsule, scale 1 mm; W_1, off Miya, Aichi Prefecture; $W_{2,3}$, off Totoro, Miyazaki Prefecture.

on egg-capsules.

The relative length of snout against head varies in rather large extent with growth of the body in the male, but the change is not so remarkable in the female (W in Fig. 25 and Table 6). On the contrary, the change of relative growth of the tail is predominant in the female rather than in the male (W in Fig. 32 and Table 7). The anterior lobe of pelvic fin very long even in the young, elongated posteriorly beyond the tip of posterior lobe when bent down posteriorly (Fig. 84 W).

The spination in the young measuring up to about 500 mm in total length much conspicuous as annotated elsewhere (p. 191), viz., minute prickles developed sparsely on whole dorsal surface of body, especially they well-developed on the tail in addition to large spines that commonly developed in the orbital rim and tail of the species referable to the genus *Raja*, (Fig. 84 W). Another characteristics in the spination is revealed as the fish attains to the adult, giving remarkable difference in the tail as shown in Fig. 35 W.

Egg-capsule: The capsule is greatest in size as compared with that of other species. It is rectangular in outline, without horns, and the capsule-wall is composed of three layers as is the case of species U, being marked as Type 8 of the capsule (Figs. 22 W and 86 W_3).

It lives in the deep seas along the Pacific coast, offing from central to southern regions of the main island of Japan (Fig. 1). The present fish is captured together with the preceding species, V, in many cases.

Remarks: The present species closely resembles the preceding species, V, in general physiognomy, but the two species are distinguishable externally from each other at least in the condition of the spination and the degree of notch of the pelvic fin, and further, they are sharply discriminated each other in the following points, such as the rostral cartilage, number of precaudal vertebrae, degree of development of the electric organ, structure of the clasper, and features of the egg-capsule.

It is interesting to note that the two species of rajids, *Raja rhina* and *R. binoculata*, are closely resembling in their external appearances, and are found together in the north western Pacific region, and such relation in features and similar tendency in habitat as revealed by the two species are also seen between the present species and the species V. At any mean, the present species seems to stand nearer *Raja binoculata* than *R. rhina*, and the comparison of the four related species can be summarized in the following.

Table 22. Comparison of external features of the body and egg-capsules in the four related species inhabiting the north Pacific.

Characters \ Species	*R. gigas*	*R. macrocauda*	*R. rhina*	*R. binoculata*
Pectoral ocellus	absent	absent	present	obscure
Ventral incision	deep	shallow	deep	shallow
Number of rows of thorns of tail in adult	reduced, one in male, three in femle	one in male, three in female, distinct	one in male, three in female, distinct	reduced, one in male, three in female
Nuchal spine	1	1	1 — 3	1
Total body-length, mm	1800 -1900	1100 -1200	800 -900	ca. 2000
Horns of egg-capsule	absent	present	present	absent

It is likely to consider that the two pairs of rajids inhabiting separately the two sides of the north Pacific may suggest that they may be descendants from a common ancestor, from which they might have been evolved in parallel.

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PLATES

PLATE I

Fig. A. *Breviraja tobitukai* (HIYAMA), adult female, 500 mm long; from off Aich Prefecture, Kumanonada.

Fig. J. *Rhinoraja odai*, n. sp., subadult male, 406 mm long, showing color pattern; from off Shizuoka Prefecture.

A
J

PLATE II

Fig. M. *Raja kenojei* MÜLLER et HENLE, subadult male, 485 mm long, showing color pattern; from off Nagasaki Prefecture.

Fig. N. *Raja acutispina*, n. sp., adult female, 407 mm long, showing color pattern; from off Yamaguchi Prefecture, the Sea of Japan.

Fig. Q. *Raja porosa meerdervoorti* GÜNTHER, adult female, 380 mm long, showing color pattern; from off Tsuiyama, the Sea of Japan.

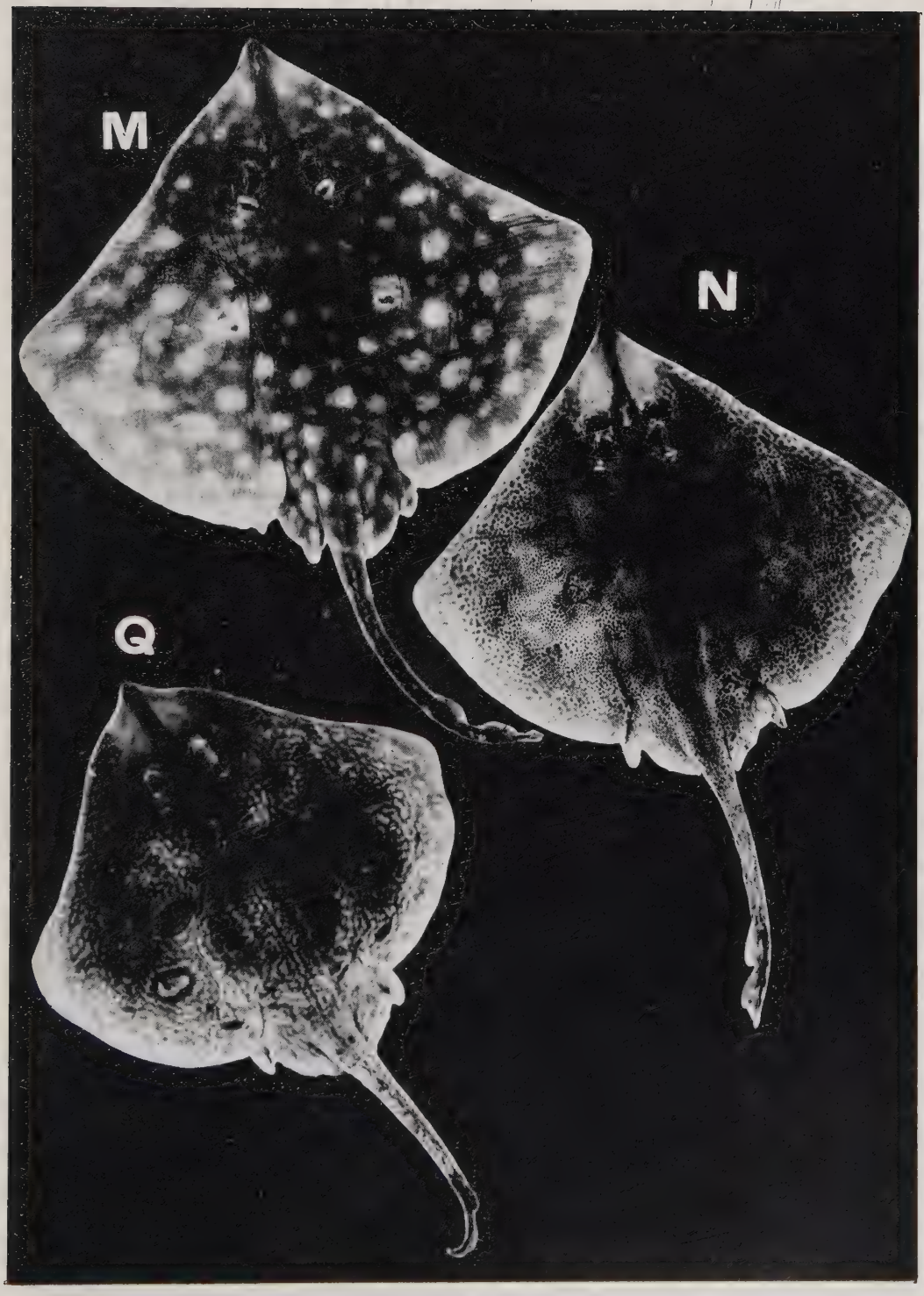
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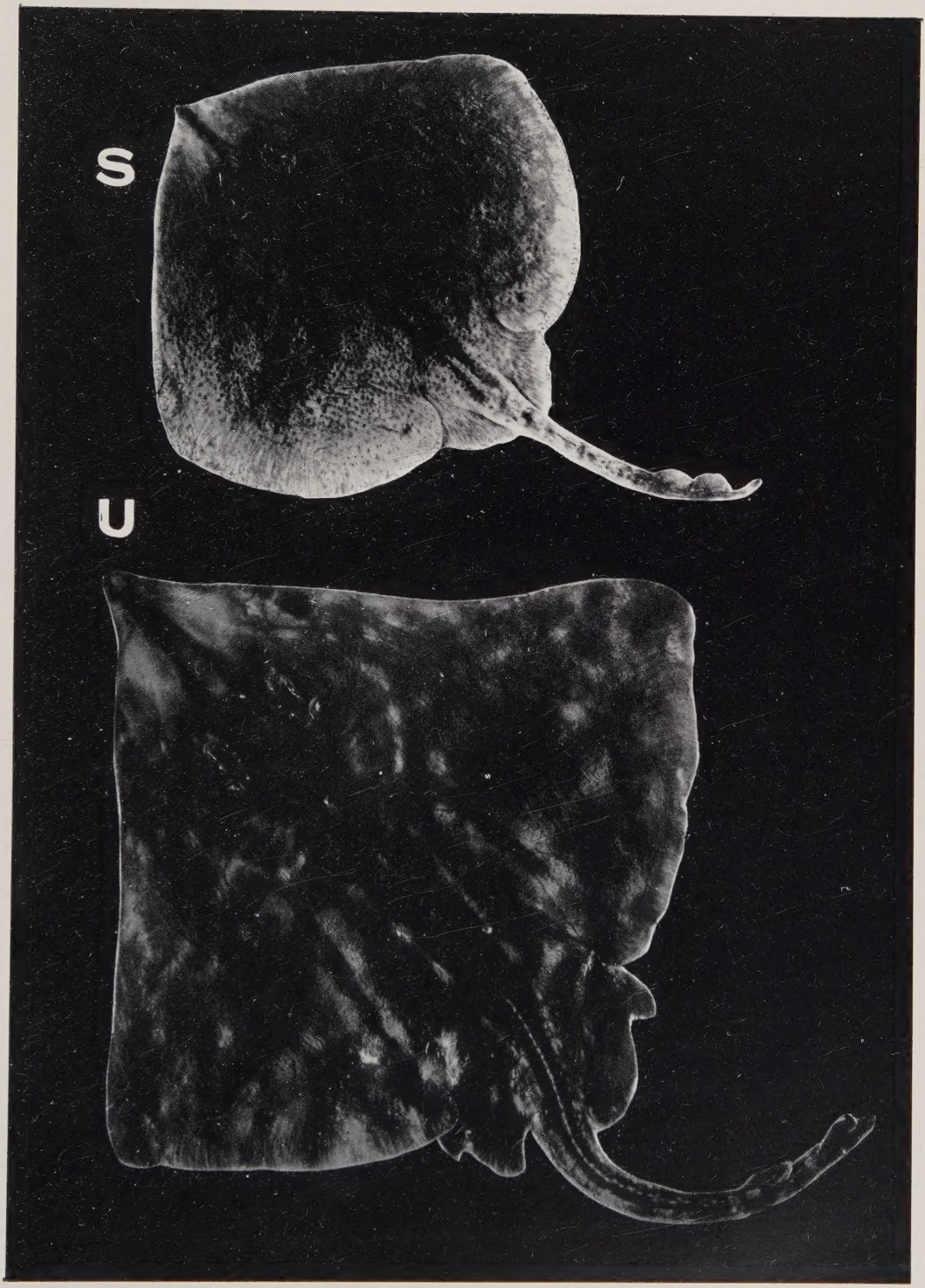
PLATE III

Fig. S. *Raja schmidti*, n. sp., adult female, 400 mm long, showing color pattern; from off Miyazaki Prefecture.

Fig. U. *Raja pulchra* LIU, adult female, 1119 mm long, showing color pattern; from off Hokkaido, the Sea of Okhotsk.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